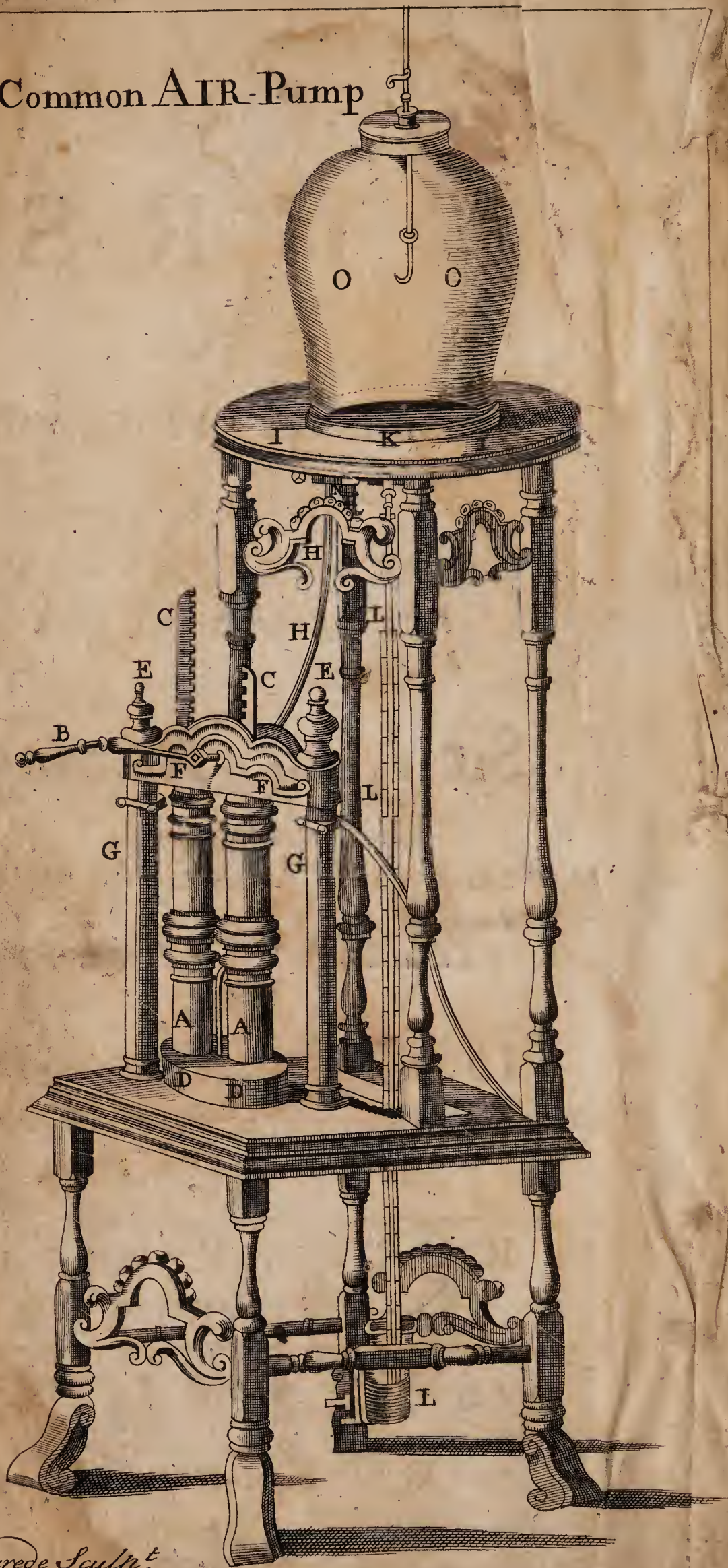


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Specimen to A

COURSE

OF

Experimental Philosophy ;

BEING

An INTRODUCTION to the true
PHILOSOPHY

OF

Sir Isaac Newton.

Containing,

MECHANICS, HYDROSTATICS,
PNEUMATICS, OPTICS, and
ASTRONOMY.

To which is added,

The Use of the GLOBES,

Done in an easy and familiar Manner for the
Use of young Gentlemen.

By ROBERT GIBSON,

Teacher of Mathematics.

~~12345678910~~

DUBLIN.

Printed for the Author, and OLI. NELSON,
at Milton's-Head in Skinner-Row, 1755.



P R E F A C E.

AS the Reader in perusing the following Sheets, will find the great Advantages which arise from the Subject, it will be unnecessary to say any Thing here in Recommendation of it: Therefore what I have to say concerning the Work, must be of the Design, and the Manner of it's Execution.

The Design then is, to explain in the most easy and concise Manner, so much of the Science, as may enable young Gentlemen, or Men of Business, to form a general Idea of the Elements, or Rudiments of it: Experience in my Profession has convinced me that few desire more, or will give themselves the Trouble to form a critical Notion of every Part of it; because they must contend with voluminous Tracts, which contain many abstruse mathematical Reasonings, that require a previous Knowledge of the Elements of Euclid, Conic-Sections, Algebra, and Fluxions: And indeed a general and concise Description or Account of any Art or Science, is best adapted to answer the Views and Ends of the greatest Part of Readers.

As to the Execution of the Work, the Subject is for the most Part illustrated by Experiments that carry with them Evidence, sufficient to satisfy the most curious Mind: There are some Geometrical Demonstrations,

P R E F A C E.

strations, which if the Reader would understand, will require the Assistance of Euclid; but as these are only a few, they may be passed by, by such as are ignorant of Geometry, taking the Premisses of the Proposition for granted. The other Reasonings, where neither Experiment, nor Mathematics can be introduced, it is hoped, will be found to be sufficiently Evident.

In drawing up this Course, I have not scrupled to take whatever I judged might best answer my Purposes, from the best Authors.

I will not pretend to say how far I have succeeded in my Intention, by rendering the Subject clear and evident; this, no doubt, will best appear to the Reader: But should it prove so, and be a Means of exciting a Desire in any to prosecute the Subject farther, my ultimate Wishes will be crowned with the desired Success.

Dublin May, 10th 1755.

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A
C O U R S E
O F
EXPERIMENTAL PHILOSOPHY.

RILEY
C H A P. I. TOWERS
Of the Properties of MATTER.

SINCE *Natural Philosophy* is not only the most pleasing, but the most useful Science for the Ease and Convenience of Life, it is no Wonder that Men in all Ages have embraced the Study of it. The numberless Improvements it has received from the *Philosophers* of the last Century, by betaking themselves to Experiments and Observations, far exceed what the Antients could ever arrive to, from the Measures they pursued by setting out upon Hypotheses or

B Sup.

Suppositions, so that what was in the utmost Obscurity and Confusion, is now rendred clear and evident; and this for the most Part is owing to the Discoveries of the Great Sir ISAAC NEWTON, To illustrate some of these Truths, or to account for the Appearances of Nature from Experiments, in an easy and familiar Way, is the Design of this Course: In order to which it will be necessary, first to consider the *Properties of Matter*.

Def. By the Word *Matter*, we understand every Thing that has Extension or Bulk, and that resists the Touch; or it is that which we call the Substance of Things, or that of which all Things do consist under different Forms and Modes.

Def. The Properties of *Matter*, or *Body*, are either *universal* and common to all Bodies, or *accidental* and peculiar to some only.

The Principal of the *universal Properties* of all Bodies or Matter, are these. 1. *Solidity*. 2. *Divisibility*, 3. *Inactivity*, and 4. *Gravity*. And of these severally.

I. *Solidity* is that Property of Body, which excludes all others out of the Place it possesseth; for no two Bodies can possibly be in one and the same Place at the same Time, for every Particle of Matter is impenetrable. Hence the Matter of the *softest Bodies* is equally *solid* with that of the *hardest*: Thus, a cubic Inch of Water will be no more compressed into less than a cubic Inch of Space, than will a cubic Inch of Iron or of Adamant.

II. *Divi-*

II. *Divisibility* is a Property of Matter which follows from the last; for since no two Bodies, or Particles of Bodies can possibly be in one and the same Place at the same Time, they must exist in different Places; and so may be considered as distinct and separate from each other, and therefore to be divided. The *actual Divisibility of Matter* will appear very surprizing from the following Experiments.

1. If an Ounce of Silver be gilt with 8 Grains of Gold, it may be afterwards drawn out into a Wire 13,000 Feet long, which shall be so closely covered with Gold, that the Silver cannot be seen with the best Microscope. Hence we may easily find, that one Grain of Gold may be actually divided into 1,950,000 visible Parts, each being the one hundredth Part of an Inch.

2. That great Philosopher, the Hon. *Robert Boyle*, Esq; who has furnished us with many Experiments on this Subject, tells us, that he dissolved one Grain of Copper in Spirit of Salt *Armoniac*, and that the Solution, when mixed with 28,534 Grains of Water, communicated a very deep and conspicuous blue Tincture to the Whole. Now, because a Grain of Water is found to be equal to .0037 of a cubic Inch, 28,534 Grains of Water will be equal in Magnitude to 105.5758 cubic Inches. If therefore a Line whose Length is the hundredth Part of an Inch, be easily discerned by the Eye, a Cube, whose Side is of that Length, will be much more discernable; but a cubic Inch contains one Million of such small Cubes, therefore 105.5758 cubic Inches will contain 105,575,800

small Cubes, the Side of each being the hundredth Part of an Inch ; and thus, by this Solution, one Grain of Copper was divided into as many visible Parts. But a cubic Inch of Copper contains almost 20,000 Grains, and therefore it may be actually resolved into 2,111,516,000,000 visible Parts : and if of this Copper there be taken a Particle of the Size of the least Grain of Sand, or one whose Diameter is the hundredth Part of an Inch, such a Particle of Copper, by the foregoing Solution, may be resolved into 2,111,516 visible Parts.

3. Mr. Boyle has also found by Experiment, that a certain Quantity of *Affa Fætida*, which he exposed to the open Air, lost the eighth Part of a Grain of its Weight in six Days : But because the Flux from odoriferous Bodies is continual, therefore it ought to be proportionable to the Time ; and hence the Weight of the Effluvia which proceeded from the *Affa Fætida* in one Minute, was the 69,120th Part of a Grain. Now the Magnitude of a Particle of Water, whose Weight is one Grain, is .00369 Parts of a cubic Inch ; therefore a Particle of the same Water, whose Weight is the 69,120th Part of a Grain, will be equal in Magnitude to .0,000,000,533 Parts of a cubic Inch : but the Gravity of *Affa Fætida* is to that of Water, as 8 to 7, and therefore the Magnitude of a Quantity of *Affa Fætida*, whose Weight is the 69,120th Part of a Grain, will be equal to .0,000,000,466 Parts of a cubic Inch. Let us now suppose that we are capable to smell the Effluvia arising from
the

the *Affa Fætida* to the Distance of five Feet only, on every Side, and that every Particle in the odorous Sphere be so large as the fourth Part of a cubic Inch, then the Sphere will consist of 57,836,916 of such Particles producing the Odour : Now all these Particles have been shewn to be equal to .0,000,000,466 Parts of a cubic Inch, therefore one of such Particles will be no more than .0,000,000,000,000,008 Parts of a cubic Inch, which is surely surprizingly small ; notwithstanding, in this Computation we have supposed the odorous Sphere equally replete with the Effluvia, without allowing the Particles near the *Affa Fætida* to be denser than those which are farther off.

4. Mr. *Lewenboeck* tells us, that there are more Animals in the Milt of a single Cod-fish, than there are Men on the Earth ; and from the Data of the Microscope he shews, that one of these Animalcula is at least 4,000,000 Times less than the smallest visible Grain of Sand. How inconceivably small then must the Globules of their Blood be ? In short, upon reasonable Suppositions he shews, that they are so much less than a Grain of Sand, as a Grain of Sand is less than the Globe of the Earth ; and tho' this Subtility of Nature is wonderful beyond measure, yet there are other Particles of Matter still more subtile than these ; for the before-mentioned Globules are as vast Mountains when compared to the Particles of Light.

Having thus far considered the wonderful Subtility of Nature, and the minute Particles into which Matter is actually divided, it remains, that we now prove, the *infinite Divisibility of Matter*.

Fig. 1. A Line AB may be infinitely divided thus: Through the Points A and B, the Extremities of the Line AB, let the Parallels CD, EF be drawn; assume any Number of Points on one Side of the Line AB, as $a, b, c, d, e, \&c.$ from B towards F, and let any Point C be taken on the other Parallel AD, and on the other Side of the Line AB; then, if from the Point C to the Points $a, b, c, d, \&c.$ there be drawn the Lines Ca, Cb, Cc, Cd, $\&c.$ these will all cut or divide the Line AB, but none of the Points of Intersection can ever arrive to the Point A: For if the Point F were taken at an infinite Distance from B, there would still be an Angle FCD, equal to CFB (by 27.1 *Eucl.*) and therefore a Line Ao, a Part of the Line AB will still remain undivided, and consequently AB is divisible in Theory, *ad infinitum.*

Fig. 2. Or a Line may be infinitely divided thus: Let a Circle be drawn, and its Diameter CD be infinitely continued on one Side, and to the Point C, one of the Extremities of the Diameter, let the Tangent AC be drawn, and the Secant AE: Now let AB be the Line to be infinitely divided; lay out upon the Radius ED, or upon the Continuation of the Diameter as many Points as you please, and with the Distance of each of these Points to the Point of Contact C, let ever so many Arches be described, they will respectively cut or divide the Line AB; and though a Point were taken upon the Diameter at an infinite Distance from the Point of Contact C, and with that Distance an Arch Co were described, the Point o of that Arch

Arch could never arrive to the Point A, inasmuch as a tangent Line can only touch a Circle in one Point, (by 13.3 *Eucl.*) and therefore a Line A o, a Part of the Line AB, will still remain undivided, and consequently AB may be infinitely divided.

III. *Inactivity* or *Passiveness* of *Matter*, is that Propensity it has to continue in the State it is in, whether of Rest or Motion, 'till it is made to alter the same by the Action of some external Force: And therefore if one Body contains two or three Times the Quantity of Matter that another does, it will also contain two or three Times the Inactivity; that is, it will require two or three Times the Force to put it into an equal Degree of Motion. And from this Principle are deduced the *Laws of Motion*, which will be explained in the following Chapter.

IV. *Gravity* is that universal Disposition of Matter whereby a *lesser Part* is carried towards the Center of any *greater Part*; thus all Parts of Matter or Bodies on the *Earth's* Surface, have a Tendency to descend to its Center: and this is called their *Weight* and *Gravitation* in the lesser Body, but *Attraction* in the greater.

Attraction is usually distinguished into that *Cohesion* and *Gravitation*.

Attraction of Cohesion is that whereby very minute Bodies, or the Particles of the same Body are mutually drawn towards each other, and made to cohere and stick together. Thus,

I. If

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A COURSE of

1. If small Glafs Tubes, open at both Ends, be dipped in Water, Claret, Spirit of Wine, or any other convenient Fluid, the Fluid will rise up the Tubes to a considerable Height above the Level; which must be owing to the Attraction of the Particles of Glafs, because the same Thing holds good in *Vacuo*, or in a Place void of Air, as under the Receiver of an Air-Pump, out of which the Air is exhausted by Pumping.

2. The Heights to which a Fluid will rise in Tubes of different Diameters, will be inversely as the Diameters. Fig. 3. Thus, if the Diameter of the Tube A be double to that of B, the Fluid will rise twice as high in B as in A.

2 3. If two polished Plates of Glafs be set parallel to each other at different small Distances, and if their lower Edges be dipped in any Fluid, the Fluid will rise between them in an inverse Proportion to their Distance asunder, as in the foregoing Tubes. If the Distance be about the hundredth Part of an Inch, the Fluid will rise about an Inch high, and so in *Vacuo*.

3 4. Let the Edges of the polished Glafs Plates be closed at AB, and the opposite Edges at CD be kept a little distant by putting a Six-Pence, or any thin Body between them; if then the lower Edges be dipped in any Fluid, the Fluid will rise between the Plates, and form an hyperbolic Curve, because the Heights of the Fluid are inversely proportional to the Distances of the several Parts of the Plates, and these as their Distances from their Point of Meeting at A, Fig- 4. For if AE, AG, AI, AD, be

be taken as Abscissæ, then EF, GH, IK, DL, will be the respective Ordinates, and consequently the Curve FHKL will be an *hyperbolic* one. 4

5. Two little Spheres of Mercury brought near each other, will mutually attract each other, and become one Sphere.

6. A piece of Loaf Sugar will attract or draw up a Fluid; in the same Manner Sap ascends in Trees, a Sponge sucks in Water, and the Glands of the Body draw in various Juices from the Blood. 5

7. Fig 5. If two Pieces of Lead with convex Surfaces be scraped clean and pressed closely together, they will attract each other so strongly as to require 100, or 150 Pound Weight, to pull them asunder. 6

Hence it is easy to account for the Formation of Bodies. For those Particles that attract each other strongly, and touch each other in many Points, form hard Bodies; those whose Particles touch each other in fewer Points, and perhaps do not attract each other so strongly, will constitute softer Bodies, as Lead, Pewter, &c. those whose Particles are perfectly round, smooth, and void of Attraction, if any such there be, will constitute a perfect Fluid; and those whose Particles are not round and void of Attraction, will form only an Heap of Dust or Sand.

This Kind of Attraction extends but to small Distances; for if the two Spheres of Mercury before-mentioned be rolled in Dust, they will not run together, for the Dust prevents Attraction. 7

Where the Sphere of Attraction ends, a repulsive Force begins; thus Water repels most Bodies, 'till they are wet. And it is upon this Principle that a dry Needle will swim upon Water, and that Flies walk upon it.

Attraction of Gravitation is that by which distant Bodies move to or tend towards one another; it is diffused throughout the solar System, and is probably extended to the other Systems of the Universe, yet at present we will consider it only with respect to the Earth, the Parts whereof would fly asunder by the diurnal Rotation, were they not kept together by the Influence of Gravity; whereby also we have daily Instances of Bodies falling on the Earth, and of others on it to tend towards its Center.

This Power, at equal Distances from the Earth's Center, is always proportional to the Quantity of Matter in the Body on which it acts; for light and heavy Bodies, falling from the same Height, descend with equal Swiftneſs, provided they meet with no Resistance from the Air. Thus, if a Piece of Gold and a Feather be let fall from the Top of an exhausted Receiver at the same Instant of Time, they will both arrive at the Bottom in the same Time very nearly, and would in the very same Time, could the Receiver be perfectly exhausted.

Hence the Forces of Gravity, whereby Bodies descend, must, at equal Distances from the Earth's Center, be as the Quantity of Matter in the descending Bodies; for if a certain Force of Gravity carries

carries a Body of a certain Quantity of Matter, with a certain Swiftneſs, then a Body of double that Quantity of Matter, will require double that Force to give it the ſame Swiftneſs: So the Weights of Bodies at equal Diſtances from the Center of the Earth, are as the Quantities of Matter they contain, and therefore the Quantity of Matter in any Body may be meaſured by the Weight.

Sir ISAAC NEWTON has proved that the Gravity of any Body within the Earth's Surface, is as its Diſtance from the Center: Thus, if the Earth's Surface were 4000 Miles, ^{from the center} and a Body on its Surface weighs a Pound, then at 3000, 2000, or 1000 Miles from the Center, that Body will weigh $\frac{3}{4}$, $\frac{1}{2}$, or $\frac{1}{4}$ of a Pound, and ſo on to the Center, where it loſes all Gravity.

Gravity on and beyond the Earth's ^{Surface} ~~Center~~, is inverſely as the Square of the Diſtance from the Center; or which is the ſame Thing, in a reciprocal Duplicate Ratio of the Diſtance from the Center, viz. at double the Diſtance it is four Times leſs, at triple the Diſtance nine Times leſs, &c. But where the Diſtances are ſmall, as $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or a Mile, their Differences are ſo very ſmall, when compared to the Radius of the Earth, that they may be rejected, for they will not occaſion any ſenſible Error in Calculation.

The Velocity or Celerity of Bodies deſcending by the Force of Gravity, muſt be directly as the Times of their Deſcent: For ſince Gravity acts uniformly, equal Times muſt produce equal Effects,

C 2

that

if in a moment a Body falls a mile in twice the time it will fall within

that is, a double or triple Time will produce a double or triple Velocity. Or if we imagine Gravity to exert itself by an infinite Number of Impulses, then if one Impulse in the first Moment of Time gives a Body a certain Degree of Velocity, in a second Moment a second Impulse will give it another, a third another, and so on; so that this Force acting perpetually on the Body, must accelerate its Velocity proportionably to the Number of Impulses; that is, proportionably to the Time of its Descent: The more swiftly any Body moves, and the longer it continues its Motion, the greater must the Space be which it runs over; so that the Space is had by multiplying the Time into the Velocity: But since the Velocity of descending Bodies are as the Times of their Descent, therefore the Space is had by multiplying the Time by the Time, or by squaring the Time. Thus, if a Body descends 2 Miles a Minute, for 2 Minutes the Space described must be 4 Miles; if 3 Miles a Minute, for 3 Minutes, the Space described must be 9 Miles, &c.

Hence 'tis evident, that the Space described

In 1 Minute will be $1 =$ the Square of 1.

In 2 Minutes will be $4 =$ the Square of 2.

In 3 Minutes will be $9 =$ the Square of 3.

In 4 Minutes will be $16 =$ the Square of 4, &c.

the Spaces being always as the Squares of the Times.

It has been found by repeated Experiments, that a heavy Body will fall 16 Feet and 1 Inch in a Second of Time, therefore in 2 Seconds it will descend

descend 4 Times as far, or 64 Feet 4 Inches ; in 3 Seconds it will descend 9 Times as far, or 144 Feet 9 Inches, &c.

Hence the Depth of a Well or Coal-Pit may be found, by observing the Time a Body is falling to the Bottom.

In the same Manner as heavy Bodies are accelerated in their Descent, it is plain they must be retarded in their Ascent. Therefore the same Velocity which a Body acquires by falling, will be just sufficient to carry it to the same Height from whence it had fallen; for the Force of Gravity acting constantly and equally against the ascending Body will diminish its rising Motion 'till it is quite destroyed.

The Center of Gravity of any Body is that Point wherein the whole Force of its Gravity is united and centred, so that whatever sustains that Point, bears the whole Weight of the Body; and if the Body be supported at, or suspended by, that Point, all the Parts of it will be in a perfect Equilibrium.

If a perpendicular Line be drawn from the Center of Gravity of a Body, it will tend towards the Earth's Center, and such a Line is called the *Line of Direction*.

The Center of Gravity continually endeavours to move downwards towards the Center of the Earth; and therefore if a Body seems to move upwards by the Force of Gravity, it will notwithstanding be found that the Center of Gravity descends.



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A COURSE of

Fig. 6. Thus, if an Angle formed by two Rulers be placed on an horizontal Plane, and the Ends be raised above the Plane; and if a Body in the Form of a double Cone be laid near the angular Point of the Rulers, it will, when let go, move towards the raised Ends, and appear to ascend, whereas it really descends: For the Center of Gravity constantly moves downwards, which will be easily obvious by performing the Experiment.

Fig. 7. Let a wooden Cylinder made hollow towards one Side, and filled with Lead, be placed on an inclined Plane, so that the Side which is nearest the Center of Gravity may lean towards the upward Part of the Plane, it will then ascend; but the Center of Gravity will at the same Time descend, provided the Inclination of the Plane be not too small.

It is therefore contrary to the Nature of heavy Bodies, and of Course to the Center of Gravity, to ascend of themselves, or not to descend, when permitted so to do.

Fig. 8. Hence it is that Bodies stand when the Line of Direction falls within their Base: But if the Line of Direction, *Fig. 9.* falls without the Base, the Body will fall; for this Line does, as it were, tie it fast to the Ground in the one Case, and pulls it over in the other.

Seeing therefore that the standing of Bodies depend upon the Lines of Direction falling within their Bases, it follows, that the larger the Base of any Body be, and the nearer its Line of Direction be to the Middle thereof, the more firmly must that

that Body stand ; and that the less the Base of any Body be, and the nearer the Line of Direction be to its Side, the less firmly must that Body stand, and therefore it may be the more easily overthrown ; because the Line of Direction is sooner and more easily removed out of the Base of the one, than of the other.

Hence it is that a Globe or Sphere rolls easily on a Plane, and that it is so difficult to make a pointed Body, as a Top, or a Needle to stand on its Point, or a thin Body on its Edge ; and that a Body slides on an inclined Plane when its Line of Direction falls within its Base, when a Sphere or Cylinder being placed thereon will roll, and that any other Body whose Line of Direction falls without its Base, will tumble over.

Hence also it is that we are in the most firm Posture when the Line of Direction falls just in the Middle between our Feet, that we are easily thrown down when it falls on or near either Foot, and that we fall, when it falls without either.

Hence also it is that we bend forward when we rise from our Seat, or go up Stairs ; that a Man leans forward or backward as he carries a Burden behind or before, or to the Right Hand or left, as he carries it on the opposite Side : and numberless other Instances of the like Nature might be added.

Having thus far explained the *Universal Properties* of Matter, it remains now to speak of some of the *Accidental Properties* which are peculiar to some Bodies only ; and more particularly those of *Magnetism* and *Electricity*.

I. Of Magnetism.

Magnetism is a very surprizing Species of Attraction peculiar to that *Fossil* called the *Magnet*, or *Loadstone*: These Stones are found in Iron Mines, and are much heavier and harder than Iron, but of that Hue; they are neither all of the same Size, Figure, nor indeed are they all exactly of the same Colour. The Properties peculiar to the Loadstone are these.

1. It attracts Iron or Steel only.

2. If a Loadstone put in a wooden Bowl-dish, little Boat, or any light Thing that will sustain it on Water, be let at Liberty, it will then turn one of its Sides towards the North and the other towards the South Parts of the Horizon; and these two Parts of the Loadstone are called its *Poles*, and the Line which is supposed to pass from one Pole to the other, is called its *Axis*.

3. Any Piece of Iron or Steel which has been touched by a Loadstone will attract and lift up a lesser Piece, and this last being touched by the former, will again attract a still lesser Piece, &c. and all these will have their Poles.

4. If a Knife be moved gently upon one of the Poles of the Loadstone, from the Handle towards the Point, it will lift up more than if rubbed to any other Part; and if you then move the Knife on the same Pole gently from the Point towards the Handle, or the same Way on the other Pole, it will lose all the Virtue it had before acquired,
and

and will not be able to lift up the smallest Needle.

5. That Point of a Needle of a Compass which has been touched upon one Pole of a Loadstone, will Point to the opposite Part of the Heavens that Pole itself will turn to ; thus, if the End of a Needle be touched on the South Pole of the Stone, it will, when set upon its Center-Pin, turn towards the North ; and if it be touched on the North Pole of the Stone, it will turn towards the South ; therefore the South Pole of a Loadstone will attract the North End of a Needle or Sea-Compass, and repel the South End, and its North Pole will attract the South, and repel the North End of a Needle or Compass.

6. All Needles which are touched by the Loadstone will point towards the North and South Parts of the Heavens nearly, and whatever Number of Degrees the Points of the Needle deviate from the true North and South Parts of the Heavens, just so much will be what is called the *Variation of the Needle*. The Needle varies in the same Place at different Times, and in different Places at the same Time. In the Year 1580 the Variation in *Dublin* was 11 Degrees easterly, and in the Year 1753 it was 19 Degrees westerly ; but how long it will continue so, Time and Observation must only determine. In some Places the Variation has been found to be 5, 10, or 15 Degrees, and at the same Time, at other Places, it has been found to be 20, 30, or 40 Degrees.

7. Bars of Iron which have stood a long Time in a perpendicular Situation will acquire the same

Virtue that a Loadstone by touching will deliver to it in a Moment : Thus, the lower End of a *Window Bar*, or a Pair of *Tongs* with which we take up Coals, and which generally stands nearly perpendicular, will have the same Virtue as we find in the South Pole of a Loadstone, and the upper End has the Virtue of the North Pole.

8. If a long slender Piece of Steel be heated red hot, and then dipped in Water perpendicularly ; or if an Iron Rod be held perpendicularly, and the upper End of it be struck by a Hammer ; either of these will immediatly acquire the same Virtue of the above-mentioned Bar or the Tongs.

9. If two polished Pieces of Steel be placed at the two Poles of a Loadstone, they jointly will take up a much larger Piece of Iron, than the naked Stone itself will take up ; for the Iron which is lifted up, touches the two Steel Poles, or the *Armour*, in more Points than the Stone itself can touch it in. But if the Armour be rusty, so as to render the Contact less, or which is the same Thing, if we apply a rusty Iron to it ; or if betwixt the Armour and the Iron we put a Body that is very thin, as a Piece of Paper, it will then lift up no more than if it were unarmed, whereas the Interposition of such sort of Bodies does not at all alter the other Effects of the naked Loadstone.

Hence it is that sometimes a weak Loadstone will carry off a Piece of Iron which is suspended to one much stronger, and this must be when the weaker Loadstone touches the Iron in more Points than the stronger does.

10. If a Brass *Whirligig*, whose Axis is Iron or Steel, be spun round upon a Table, and then taken up by a Loadstone, it will keep turning much longer than if it be left to move on the Table; because the Friction is taken off, when it is suspended by the Loadstone, that it suffered when it was on the Table.

11. If a Loadstone be let to take Rust, so as to get into its Pores, its Texture will thereby be destroyed, and the Stone will lose much of its Virtue; and in like manner if it be put into a Fire, its Texture by that Means will be more destroyed, and therefore it will lose much more, or perhaps all its Virtue.

12. The only Remedy to prevent a Loadstone from Rust, or of being injured by too much Heat, is to surround it with a Coat of Iron; for the Iron will admit a much freer Passage to the magnetic Matter, than the Air does, for it bends itself and continues its Course in the Iron; and therefore the Pores cannot suffer so much as when the Stone is left naked in open Air.

13. If a Loadstone be sawed into several Pieces, each of these will have its particular Poles, which may be found by letting them swim in small wooden Cups or Boats, as before.

14. It will be necessary here to observe, that the Needles of Surveying Instruments are frequently out of Order, and require often to be touched. The Reason of this, as I take it, is, that as soon as a Surveyor has finished his Survey, he laps up his Needle in a Scrap of Paper, and throws it in any Manner into the Box by the Side of the Center-

Pin, and in that Manner lets it lie 'till the next Time he has Occasion to use it; if this proves a long Time, it is very probable his Needle will be out of Order: For the Needle, by the Virtue which is infused therein by the Touch of the Loadstone, as before, has a Tendency to point towards the North and South Points of the Heavens, and it will use all its Effort so to do, and will actually do so, if it be laid on its Center-Pin on an horizontal Plane in a Place where Iron is not near it to alter or change its natural Situation. Now, because the Needle, when thrown by the Side of the Center-Pin, is debared of all its Power of pointing where it naturally would, tho' it exerts all its Power so to do, by the magnetic Virtue infused therein; it thereby suffers so great a Conflict, that it is deprived of its usual Strength and Effort, by exerting it to no Effect, and thereby its magnetic Virtue is some way or other so withdrawn from it, that it becomes of little or no Use 'till it receives a new Touch; whereas, if the Needle be kept on its Center-Pin in an horizontal Position, as above, or if the Instrument be constantly used, the Needle will be many Years without requiring a new Touch. I am no Stranger to the Complaints of Surveyors concerning their Needles, and therefore I am the more confident in asserting that a Needle seldom, if ever, requires touching, which is constantly used, or kept on its Center-Pin; but the Cause of its not playing well, as it is termed, or not pointing duly as it ought to do, must either be owing to the Point of the Center-Pin being turned, so that the Friction of it against the Cap impedes the

the

the Motion of the Needle ; or else that the Cap of the Needle is pricked, or a Hole is made therein by the Center-Pin being too sharp, from a Jolt or Jump. So that in the general I am satisfied that Surveyors and Mariners would have fewer Complaints of their Needles and Compasses, were they kept always on their Center-Pins, except in carrying on Horse-back or on a Carriage, where the Motion is very violent.

15. I have often heard it asserted, that Needles touched by different Loadstones had different Tendencies towards the North and South Points of the Heavens, and therefore that different Needles had different Variations in the same Place ; but from repeated Experiments, I have found the contrary. If indeed, Mathematical Instrument-Makers do not take sufficient Care to put the Ring in the Box, so that the 360th and 180th Degrees thereof shall exactly correspond with the Line on the Middle of the Index, and this again with the narrow Slits of the Sights, and with the Hairs in the Middle of the wide ones ; the Difference arising in the Degree pointed to by two or more Needles, is to be attributed to the Inaccuracy of the Instrument-Maker, and not to any different Tendencies acquired by Needles being touched by different Loadstones.

Lastly, The attractive Quality of the Loadstone acts in an inverse or a reciprocal Ratio of the Distances the Iron or Steel is from the Stone ; that is, at a single Distance, the attractive Force is four Times greater than at a double Distance, and nine Times greater than at a triple Distance, &c.

II. Of Electricity.

Electrics per se, are such Bodies as will, when heated by Attrition, Rubbing, or Friction, attract and repel all light Bodies at the Distance of 10 or 15 Inches: Such are *Glass, Jet, Sealing-Wax, Agate*, and almost all Manner of *Precious Stones, Silk*, and *Amber*; from which last, on account of its general Character of taking up or attracting Straws, Pieces of Paper, and other light Bodies, it bears the Name of Electricity. *Non-electrics per se* are those Bodies which cannot produce that Effect when rubbed, but they attract the electrical Effluvium or Matter from the *Electrics per se*, 'till they become replete, and then they produce the same Effects.

1. If a Glass Tube of about an Inch and an half Diameter, and two or three Feet long, be heated by Rubbing, it will alternately attract and repel all light Bodies. 2. It will not attract by being heated without rubbing. 3. Any light Body being once repelled by the Tube, will never suffer itself to be attracted again, 'till it has lost its Effluvium by touching some *non-electric per se*. 4. If the Tube be rubbed with a moist Hand, or if it be touched by any Thing that is wet, it destroys the Electricity. 5. It attracts best when it is first rubbed with Bees-Wax, and after with a dry woollen Cloth. 6. When it is rubbed well, so as to be in good Order, if the Finger be moved by it, at the Distance of about half an Inch, the Vapour issuing therefrom, will snap and crackle against the Finger,

ger, and a Flash of Light will appear, if the Place be dark.

Fig. 10. If under a Glass Globe, or Glass Cylinder, fixed upon an Axis, be placed a Cushion covered with Buff Leather, and over it be hung a String of Wires from an Iron Bar which is sustained by Silk Threads, proceeding from four wooden Pillars, and if the larger Wheel be turned brisk, and the Cushion be kept close to the Cylinder, (which is affected by a Screw passing through the Spring to the Extremity of which the Cushion is fixed;) then by the Attrition of the Cushion against the Glass, the Globe or Cylinder will emit a copious Electrical Effluvium, which being attracted by the Wires, will from thence be conveyed into the Iron Bar: From whence many Experiments may be performed, the principal of which are these.

1. If you put your Finger, or any other non-electric Body, near the electrified Bar, it will attract the Vapour visibly, and a Flame will issue, crackle and snap in coming from the Bar, and in the Finger will be felt a slight prickling Pain.

2. If a Person standing upon a Cake of Wax or Rosin, lays hold of the electrified Bar with his Hand, his Body will be filled with the electric Fluid which issues from the Bar through his Arm; but this electric Matter will be lost in the Floor, if the Cake, or whatever else he stands upon, be not an *electric per se*. And if any Person touches any Part of him who is so electrified, the electric Flame or Matter, will issue from the Part where he is touched,

touched, into the Finger that touched him, with a Snap, and will raise a sudden prickling Pain in both.

3. If the electrified Bar be touched by any electric Body, as Glass or Wax, the Spark or Flame will be scarcely sensible, and therefore the Consideration of it is avoided.

4. If two Persons standing on *Electrics per se*, be equally replete with the electrical Matter, touch each other, nothing will be seen to issue, so as to cause either Flame, Snap, or Sensation; because in this Case, they may be looked upon as *Electrics per se*, and therefore will rather repel than attract each other: For if two Feathers be tied with small flaxen Threads, and hung close to each other over the Bar before it is electrified, upon electrifying the Bar, they become in a Moment electrified, and then they repel each other.

5. If two Persons stand on Cakes of Wax, or on separate electric Bodies, and if one of these only be electrified, then as often as either touches the other, so often will the Person who is not electrified attract the electrical Matter from him, that is, 'till they are equally replete with it: On their first Approach, the Snap and Sensation will be strong, the second Time it will be weaker, the third still less, and so on; 'till the electrified Person communicates to the other Half of the electrical Matter he at first contained, except the little that is dissipated at every Snap: For if another Non-electric touch each Person, the like Sensation will arise from both; and if the electrified

Persons

Persons then touch each other, the Effect will not be sensible to either.

6. If there be three Bodies electrified which are of a given Magnitude, but different Density, one of Wood, another of Stone, and the third of Iron; then, if Bodies of the same Kind, which are not electrified, be held seperately towards each of them, the Sensation, Flame, and Snap will be greatest from the densest Bodies, weaker from the less dense, and exceedingly weak from the Bodies that are least dense. Again, if the densest touch the rarest Body, the Effect will be stronger than when the rarest Bodies touch each other, and weaker than when the densest Bodies approach each other.

7. If a Wire be electrified in the Dark, and a Non-electric be held at seven or eight Inches Distance from the End thereof, there will be then seen to issue from the Wire, a continual Stream of luminous Matter, which will diverge to the Non-electric: The Divergency will gradually lessen, 'till it becomes parallel, by approachiug nearer with the Non-electric. Again, if the Non-electric be held, not directly before the End of the Wire, but wide and distant about two Inches therefrom, the issuing Matter will describe curvilinear Rays towards such Non-electric.

8. If a Person holds a spoonful of warmed Spirits of Wine or Oil of Turpentine within an Inch or two of the Finger of a Person who is electrified, the Fluid and Spoon being Non-electrics, will attract the electrical Matter from his Body, so as to set the Spirits or Oil on Fire.

9. If a Person be bled in the Arm, and the Height to which the Blood rises be well observed: If this Bleeding Person be immediately electrified, his Blood will be found to rise to almost double the former Height, and the Globules towards the Top of the Stream, being now electrified, and therefore may be considered as *Electrics per se*, will repel one another: But as soon as he leaves the electric Body upon which he stands, or disengages himself from the Bar, the Blood will immediately lessen in its Height; and it will alternately rise and fall as he touches and quits the Bar. The like may be done by electrifying a Copper Fountain when the Jet is set going.

10. If a light Wheel of Paper, made in much the same Manner with the Leaves of a Water-Mill, having a Needle for its Axis, be thence suspended by a Loadstone, and held opposite the End of an electrified Wire or Sword, it will be carried round with a surprizing Velocity.

11. If a Vial, closely covered with Lead, or any other Non-electric, be filled with Iron or Steel Filings, and securely corked up, has a Wire inserted through the Cork, and Filings contained in the Vial, the Cork being well covered with Wax, be electrified, the Vial by that Means will contain a great Quantity of Effluvium: If then a Person takes hold of another Wire or Chain issuing either from the Top of the inserted Wire, or from the Bar, by one Hand, and he gives his other Hand to another, and that second his other Hand to a third, and so on with ever so many Persons; then, if the last Person of this Chain of Persons touches the
Bar

Bar with his Finger, or a Wire, the electric accumulated Matter will instantly explode, and all the Persons composing the said Chain, will feel a very sensible Shock at the same Moment ; which Shock may be encreased to a surprizing Degree, if two or three such Vials be electrified in the like Manner ; which will be manifest from what has been already said.

The Cause of Gravity, as well as those of Magnetism and Electricity, having not hitherto been sufficiently accounted for by the most Ingenious, we therefore wave any Attempt of that Nature.

C H A P. II.

Sir ISAAC NEWTON's Laws of Nature, or Laws of Motion explained.

Law I.

Every Body will continue in its State of Rest, ^{or} of moving uniformly in a right Line; except so far as it is compelled to change that State by Forces impressed.

THERE being in all Bodies a certain inactivity whereby they oppose every Change; therefore a Body at Rest would remain so for ever, except it were compelled to change that State by a Force impressed. In the same Way, a Body in Motion would for ever continue to move forward in a Right Line, if some Force did not oppose its Progress; for there is not required a less Force to stop the Motion of any Body, than was before necessary to give that Body Motion. Since then the *Vis Inertiæ*, or Inactivity of Matter equally resists equal Changes, it will not be less powerful to continue a Body in Motion, than to preserve a Body in a State of Rest.

Law II.

The Change of Motion is always proportionable to the moving Force impressed, and is always according to the right Line in which that Force is impressed..

For if any Force or Power gives a certain Motion to a Body, a double Force will give it a double, and a triple Force a triple Motion : And this Motion will be in the same Direction with the Force impressed, because it solely arises from it ; nor can any Body change from this Direction it acquires from the first impressed Force, except it be actuated on by some new Force which is in a different Direction : So that if this new Force be in the same Direction with the first acquired Motion of the Body, it will add to that Motion ; and if it be opposed to the first Motion in an opposite Direction, it will retard it ; but if it be impressed on the first Motion in an oblique Direction, it will be compounded of the two Forces as will be just now shewn.

Law III.

Re-action is always equal and contrary to Action ; or the Action of two Bodies upon each other are always equal, and in contrary Directions. That is, by Action and Re-action equal Changes of Motion are acting upon each other, and these Changes are impressed towards contrary Parts.

Whatever presses or draws another Thing is equally pressed or drawn by it, but in a contrary Way.

Way. If a Horse draws a Load, he is equally drawn back by it ; for as much as he promotes the the Progress thereof, so much is he retarded in his Motion ; that is, he, in Effect, is drawn back ; for the same Force of Muscles and Sinews which he exerts to draw the Load, would, if he were freed from it, carry him to a much greater Distance ; and consequently so far as his Progress falls short of that Distance, he is in Effect just so far drawn back ; and the same Motion he communicates to the Load, so much does he loose of his own, the Load retracting upon him with the same Force he acts upon it : For which Reason if the Weight of the Load be increased so as to require the Horse's whole Strength, no Motion will ensue.

When a Loadstone attracts Iron, it is equally attracted by it. For let a Piece of Iron and a Loadstone of equal Weight be suspended by Cords of equal Lengths, and let them be within the Sphere of Attraction ; then they will mutually move towards each other, and meet at the middle Point of their first Distance ; And if either be fixed it will attract the other. And the like obtains in all Kinds of Attraction.

If there be two Boats of equal Dimensions, or of the same Quantity of Matter placed by each other, if a Person in either pushes the other Boat they will both equally recede from the Place they were in together. But if one Boat contains double or triple the Quantity of Matter of another Boat ; and these Boats be placed by each other, if a Person in either pushes the other Boat, the smaller Boat will recede twice or three Times as far as the larger ;

ger ; that is, the Velocity of the smaller Boat will be two or three times greater than that of the larger, tho' the *Momentum*, or Quantity of Motion in each, that is, the Force impress'd upon each will be the same ; Action and Re-action being equal and contrary. In the same Way, if a Man in a Boat, which lies on one Side of a Man of War, whose Quantity of Matter is 1000 Times greater than that of the Boat, the Boat will then fly 1000 Times farther from the Man of War than the Man of War will from the Boat ; thus, if the Boat flies 10 Feet from the Man of War, the Man of War will have flown but the one hundreth Part of a Foot from the Boat ; yet the Moment, or Quantity of Motion in each will be the same. Hence, if one in a Boat pushes against a Rock or Shore, the Boat will recede from either, while the Rock or Shore is immoveable : For the whole Earth, of which either is but a Part, is inconceivably large with respect of the Boat ; and therefore the Velocity of the former may be esteemed nothing in respect of what is found in the latter.

Or a Stone in the Air as much gravitates the Earth as the Earth does the Stone ; that is, a Stone as much draws the Earth towards it as the Earth does the Stone ; but because the Quantity of Matter in the Stone is infinitely less than that in the Earth, the Velocity of the Stone will be infinitely greater than that of the Earth ; for, physically speaking, that of the Earth will be nothing, which will easily appear upon a Calculation.

When a Boat is rowed with Oars, the Ends of the Oars drive the Water backwards, but the Water

ter acting upon the Oars forces them with the Boat to which they are fixed forwards: For if the Oars had nothing to act on, there could be no Reaction or Motion, since no Force could be impressed. Seeing therefore a Boat is carried forwards by the Re-action of the Water on the Oars, it follows that the broader the Blades or Ends of the Oars be, or the greater Number there are of them, or the swifter the Strokes are, the greater the Action must be against the Water, and of Course the greater the Re-action, and the Progress of the Boat must be.

Hence because swimming is nothing else than a Rowing with Hands and Feet; it is, that Persons are carried forwards in the Water. In like Manner Birds fly; for, by striking the Air downwards with their Wings, the Reaction of the Air drives them upwards; and in striking the Air with their Wings backwards, the Reaction of the Air gives them a progressive Motion.

By these Laws it will be easy to prove, that,

If a Body be acted upon by two Forces in different, but not opposite Directions, they will describe the Diagonal of a Parallelogram in the same Time, that each Force acting seperately upon it will describe the Sides.

Fig. 11. Let A represent a Ship at Sea, and that it is drove by the Wind in the Direction of the Line AB, at the Rate of eight Miles an Hour from A to B, in a Current that sets in the Direction of the Line AD, at the Rate of four Miles an Hour: By these

these two Forces acting together on the Ship at A, it will at the End of the Hour be found at C, after having described the Diagonal of the Parallalogram AC.

For the Force AB will not hinder the Ship to approach the Line CD, which is parallel to it; neither will the Force AD hinder the Ship to approach the Parallel BC: therefore the Ship at the End of an Hour will be found in the Point C.

If both Forces act upon a Body so, as each will give it an uniform Motion, the Diagonal described will be a right Line as above. But if one of the Forces acts in such a Manner as to make the Body move faster and faster, while the other acts uniformly on it, then the Diagonal described by these Forces jointly will be a Curve: Thus, *Fig. 12.* Suppose one Force to drive a Body from A in the Direction AF, so as to make it move through the equal Spaces AB, BC, CD, &c. in equal Times; then suppose another Force to act upon a Body at A, in the Direction of the Line Af, in such a Manner as to make it describe the unequal Spaces Ab, cd, de, &c. in equal Times; these two Forces will cause the Body to describe the Curve A,g,b,i,k,l. If the Spaces Ab, bc, cd, &c. be the Spaces through which a Body falls by the Force of Gravity in equal Times, the Curve A,g,b,i,k,l will be such as is described by a Projectile, as a Ball from a Gun, and is called a *Parabola*. For, suppose in the same Time that the Force of Powder drives the Ball from A to B; that Gravity would cause it to fall from A to b, the Body in that Time would describe the Diagonal Ag, by the foregoing Rule: But, in

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double

double Time, Gravity will cause the Body to descend four times as far, or to c ; and the force of Powder will carry it to twice its former Distance, or to C ; so that at the End of the second part of Time the Body will be found at b : And in like Manner, at the End of the third Part of Time the Body will be found at i ; at the fourth, at k ; at the fifth, at l , &c. and thus the Curve, (which by Writers of Projectiles, is demonstrated to be that) of the Parabola, is generated.

It will be here necessary to say something concerning *absolute* and *relative Motion*.

Absolute Motion, is the Motion of a Body when it moves from another which is at Rest. And *relative Motion*, is the Motion of a Body when it moves from another which is also in Motion, at the same Time.

We cannot be sure that any Thing we know of is at Rest; for though we may imagine any Body to be at Rest, yet there may be still some very distant Body perfectly quiescent, with respect to which it may change its Position, or really move.

Whenever the whole is moved, all the Parts will partake of that Motion, though these Parts are relatively at Rest, or with respect to each other: Thus the several Parts of a Ship under Sail, as well as those of the Loading, though they are relatively at Rest, yet they are all really in Motion along with the Ship: And therefore every particular Part is disposed to move with the same Celerity as the whole, though it should be

be separated therefrom, or though the Rest shou'd stop on a sudden and their Motion cease. Thus if a Ship be under Sail, and a Person lets a Stone or any heavy Body fall from the Mast Head, it will fall exactly at the same Distance from the Foot of the Mast, as if the Ship were at Anchor; and all Motions upon the Deck, and Bodies hanging perpendicularly, are the same as if the Ship were at Rest, every Part having a Disposition and a sufficient Force to move with the same Degree of Celerity with the Ship; for, if the Ship were suddenly stopped by striking against a Strand, or any large Body; the Persons from the Disposition of Motion in them, would fall forwards, and at first setting off, they will be apt ~~to~~ to fall backwards, in as much as the Motion is not as yet communicated to them.

If a Stone be whirled about in a Sling, the Stone and that part of the Sling in which it lies, have the same Velocity because they describe the same Circles: But because all Bodies affect to move in a right Line, the Stone would fly off in every Part of its Orbit, if it were not prevented by the String; for as soon as the String is let go, or breaks, the Stone will no longer continue its Circular, but will break out into a rectilinear Motion. This Endeavour of the Stone to break out of its circular Motion, into a Tangent, is called its *Centrifugal Force*, and is the Cause of stretching the String; for the swifter the Stone is whirled and the greater its Weight be, the greater will be the Tension of the String,

A or the more it will be stretched: And this Centrifugal Force can proceed from no other Cause but the Endeavour which all Bodies have to move in a right Line: And in like Manner if the Earths Motion were suddenly to cease, all moving or loose Bodies thereon would fly off with a violent Motion.

C H A P. III.

*Of the simple mechanical Powers, namely,
 1, The Ballance. 2, The Lever. 3, The Pulley. 4, The Axis in Peritrochio, or Axis in the Wheel. 5, The Wedge, and 6, The Screw. With the Nature of Pendulums.*

IF two Bodies of different Quantities of Matter or Bulks be impelled with equal Forces, they are then said to have a like Moment or Quantity of Motion, tho' the Velocity or Celerity of the Greater will be less than that of the Lesser; as before, and therefore a Body however small, may have a Moment equal to that of another Body how ever great. Thus if there be two Bodies whose Quantities of Matter are as 10 to 1, and their Moments equal, then the Celerities will be as 1 to 10, or the greater Bodies Celerity will be 10 Times less than that of the lesser; that

that is when the Moments are equal, their Celerities will be reciprocally proportionable to those Bodies; and the Product arising from the Quantity of Matter into the Celerity of one, will be equal to that which arises from the Quantity of Matter into the Celerity of the other: And on the contrary, when these Products are equal, their Moments or entire Forces are so too, and therefore the Moments of Bodies are usually expressed by the Quantity of Matter into the Celerity. Upon this Principle depends the whole of Mechanics. For in all Engines whatsoever, the greatness of the Weight or Resistance, must be compensated by the Celerity of the Power to raise it; that is, the Celerity of the Power must be to that of the Weight as the Weight is to the Power.

I. Of the Ballance.

A Ballance is a Beam supported by an *Axis* upon which it turns, which *Axis* is the *Center of Motion*; the Parts of the Beam lying on each Side of it are called the *Brachia* or *Arms*: And those Parts of the Arms to which the Weights are applied, are called the *Points of Suspension*; And it Matters not, whether the impending Weight be sustained by a short or a long Cord, for Gravity acts equally at small unequal Distances.

That a Ballance may be exact it is requisite, 1st. that (*Fig. 13.*) the Center of Gravity of the Beam be a little below the Axis, or Center of Motion, for when there is an Equilibrium the

Beam

ie any thing less than a mile

1 Beam will not rest but in an horizontal Position, and therefore the Weights which are compared together are equal. But if the Axis be below the Center of Gravity (*Fig. 14.*) and the Center of Gravity be moved out of the Perpendicular Line, it will not return from its Tendancy to move downwards, for which Reason the Weights will appear to be unequal, though in Reality they are not so. And the same Inconvenience will arise, if the Axis passes, through the Center of Gravity, (*Fig. 15.*) for notwithstanding the Equilibrium, the Beam will rest in any Position.

2. The Arms ought to be of equal Weight and Length.

3. The Points of Suspension should be in a right Line with the Center of Gravity of the Beam.

4. The Friction of the Beam against the Axis should be as little as possible. Then equal Weights shifted to either Scale will preserve an Equilibrium. For if the Beam be considered as an inflexible Line whose Middle Point is the Center of Motion, and the Extremities, the Points of Suspension; it is plain, if it be moved on its Center that those Points will describe equal Arches, and therefore that they have the same Celerity which being multiplied into equal appending Weights, the Products or Moments being equal, an Equilibrium will arise.

But if the Center of Motion be not in the Middle of the Line, the Points of Suspension will not describe equal Arches, for the Arches described

described by them though they are like, will not be equal to each other, but will be proportionable to their respective Distances from the Center of Motion; and therefore the Celerities of these Points will be proportionable to their Distances from the Center of Motion: Wherefore in Order that an Equilibrium may be obtained, the Appending Weights must be reciprocally Proportional to the Distances of the Points of Suspension from the Center of Motion; in Order that the Moments may be equal.

Fig. 16. Thus if the Distance of the Axis from the Points of Suspension be as 6 to 5, the appending Weights must be as 5 to 6 to preserve an Equilibrium: For 6 multiplied into 5, will be equal to 5 multiplied into 6: And therefore the Moment is the same on either Side. That is 5 Pounds at the Distance of 6 Inches from the Axis, will maintain an Equilibrium with 6 Pounds at the Distance of 5 Inches.

Hence a deceitful Ballance may be constructed, for 6 Pounds will appear equal in weight to 5 Pounds, so that a Person may be defrauded of a Pound at every Draft: But if one be suspicious of any Design of this Nature, let the Weights be shifted into the contrary Scales and the Defraud will instantly appear, for 6 into 6 is greater than 5 into 5, and then the Moments will be unequal.

Fig. 17. If several Weights be appended at several Distances from the Axis, and if the Moment or Sum of the Products of each Weight into its Distance on one Side, be equal to the Moment

or

or Sum of the Products of each Weight into its Distance on the other Side, an Equilibrium will arise.

Thus 10 into 5 = 50

6 into 4 = 24

7 into 10 = 70

3 into 8 = 24

4 into 7 = 28

Sum 98

= 98 Sum

Hence it is easy to conceive how one and the same Weight may ballance different Weights:

Fig. 18, Thus, one Pound at the Distance of 20 will either ballance 20 Pound at the Distance of one, 10 Pound at the Distance of 2, 5 Pound at the Distance of 4, 4 Pound at the Distance of 5, 2 Pound at the Distance of 10, or one Pound at the Distance of 20:

Hence also, it appears that the Weights of different Bodies may be found by one Weight only, as in the *Statera Romana* or Steel Yard, *Fig. 19*. Thus, if a Beam AB be divided into 11 equal Parts, and if the last 10 of these or the Distance CB be again subdivided into 10 other Parts, the Distance CB will then consist of 100 equal Parts: Now if the Axis or the Center of Motion be placed at C, at the Distance of one of the larger Parts from the Point of Suspension A, from whence any Body W whose Weight is required, must be appended; and if on the contrary Arm, there be a moveable given weight P appended; it is plain that by removing it to, or from the Center of Motion C, till an Equilibrium be maintained, that the Weight of the Body W may be discovered: For if the Weight P at the Distance of 8 Equiponderates that

that of W , at the Distance of one, from C ; then the Weight W , is eight Times as heavy as the given Weight P .

II. Of the Lever.

A *Lever* is supposed to be an inflexible Line void of all Gravity; though such as are commonly used, are both flexible and weighty.

In every Lever there is an immoveable Point, about which as a Center all the Parts of it turn; and whatsoever supports that Point is called the *Fulcrum* or *Prop*: And with regard to the different Situations of the moving Power and Prop, the Lever is divided into three Kinds.

1. Where the Fulcrum is placed between the moving Power and the Weight to be raised.

Thus, *Fig. 20.* if in raising a Weight W of 100 Pounds, there be applied a Lever WP whose Length is 36 Parts, and the Distance of the Weight W to be raised to the Fulcrum F , be 6 of those Parts; then a Weight or Power of 20 Pounds being applied to the other End of the Lever at P , will be sufficient to bring it to maintain an Equilibrium, as in the Ballance; because the Moments 100 into 6, and 20 into 30 are equal; which Power P if it be ever so little encreased will be sufficient to raise the Weight W .

Such Levers are commonly used for raising Stones, and in this Case the more weighty the Lever or Quarry-crow is, the more useful must it be; because the Weight of that Part of the Crow which lies beyond the Fulcrum, far exceeds the

G

other

other Part in Length, and acting in Conjunction with the Power, thereby facilitates the raising of Stones or other Weights.

To this kind of Lever may be reduced Pump-handles; and several other Instruments, such as Scissars, Pincers, Snuffers, &c. which are composed of two Levers whose Fulcrum is the Revit:

2. The second kind of Lever has the Fulcrum at one End and the Power at the other. *Fig. 21.*

This kind of Lever is therefore never used but in Cases of Necessity, or where the Weights to be raised cannot be managed in a more convenient Manner: because it is evident, the Power which is requisite to raise the Weight, must be greater than it, As in Case of a Ladder, which being fixed or kept down at one End, is raised by the Assistance of one or more Men, 'till they arrive to its Center of Gravity; and then it becomes a Lever of the third Kind.

To this second Kind of Lever may be reduced Oars, Wheel-barrows, Drays, Cars, Nut-crackers, Cutting-Knives the moving of Doors on Hinges, &c.

Since in this Lever the Distance from the Weight to the Fulcrum, is less than is the Power to it; it is evident that there cannot be a Ballance in any Case but where the Weight exceeds the Power.

If two Men carry a Burthen between them, as a Sedan-chair, a Weight on a Hand-barrow or on a Pole or Staff; it is plain they both sustain the Weight, and that when it is in the middle between them, that each sustains one half of the

the Weight: But when the Weight is nearer to one than the other, he bears most that is nearest to it, in that Proportion that the other is farthest from it: For the respective Powers are reciprocally as their Distances. Now the Poles, may be imagined as Levers of the second Kind, and each Man's Shoulder as a Fulcrum with Respect to the other; so that the nearer the Weight is to the Fulcrum, and the farther the Power is from it, the greater is the Advantage.

This is also applicable to the Case of two Horses of unequal Strength, to be yoked so to a Draft that each may draw in Proportion to its Strength; which is done by dividing the Beam so, as that the Point of Traction be as much nearer to the stronger Horse, as his Strength is greater than that of the other.

3. A Lever of the third Kind, is when the Power is between the Weight and Fulcrum.

Fig. 22.

To this are generally referred the Bones of a Man's Arm or Leg; for when we lift a Weight in the Hand, the Muscle that is exerted to raise that Weight is fixed to the Bone, about one tenth Part as far from the Elbow as the Hand is; and the Elbow being the Center about which the Arm turns, the Muscle therefore must exert a Force ten Times greater than the Weight raised.

Hence we may easily calculate the Strength of the Muscles in any Part of the Body, by trying how much they can lift at any Distance from the Center. ~~X~~

Hence also any Thing is with most Difficulty lifted at Arms Length, the Shoulder being the Fulcrum, and the Weight being at a greater Distance from it than if it were at the Wrist or Elbow; and a Stick is more difficultly raised at full Length than at the Middle, because the Center of Gravity of the Stick in the former Case, is farther from the Fulcrum than in the latter.

In a Compound Lever made of several single Levers of the same Kind, the Power will be to the Weight in a Ratio compounded of the several Ratios, which those Powers severally have when applied to the Weight. Thus *Fig. 23.* If the Power of the Lever A be to the Weight to be raised as 1 to 5, that of the Lever B to the same Weight as 1 to 4, and that of the Lever C to the same Weight as 1 to 5; then the Power of one Pound being applied to the End of the Lever C, will support the Weight of 100 Pounds at the End of the Lever A, since 5 into 4 and that into 5 are equal to 100, and 1 into 1 and that into 1 will still make but 1: For at the right Hand End of the Lever A, the Weight will be one fifth less, or 20 Pounds; at the right Hand End of B, it is one fourth less than 20 Pounds, or 5 Pounds; and again at the right Hand End of C, it is 5 Times less than 5 Pound, or but one Pound.

III. Of the Pulley.

The *Pulley* is a small Wheel that turns about its Axis, which has a drawing Rope passing over it

it, and is used in raising Weights; it is of two Kinds; fixed, and moveable.

The fixed Pulley is of no other Use but to raise the Weight in a different Direction, than in being over it to raise it perpendicularly, since it does not in the least assist the Power; (*Fig. 24*) for whatever be the Space through which the Power P moves by drawing the Rope AP , the Weight W must in the same Time be drawn through an equal Space; and therefore the Weight will be supported by a Power which is equal to it. *N. B. In all the following Machines of Pulleys, W signifies the Weight to be raised, and P the Power.*

Fig. 25. When a Pulley to which there is a Weight fixed, is placed in the double of a Rope, whose End is fastned to a Hook H ; it is plain that to raise the Weight one Foot, each Side of the Rope must be shortened one Foot, counting from the Hook downwards; that is, the Power must be raised two Foot in Order to raise the Weight one, or the Celerity of the Power must be double to that of the Weight; and also because the Power sustains but half the Weight, the other half being sustained by the Hook; the Power is to the Weight as 1 to 2, and therefore its Moment will be equal to the Moment of the Weight and will sustain it: And this is just the reverse of the fixed Pulley.

In a Machine consisting of some fixed and other moving Pulleys, and which have one common Rope to all; if one End of the Rope be fixed, the Power must be to the Weight as one is to twice

twice the Number of moveable Pulleys, for the Celerity of the Power is to that of the Weight in a like Proportion: Thus, (*Fig. 26*) if there be one fixed and one moveable Pulley, the Power must be half the Weight; and if two Pulleys are fixed, and two moveable, (*Fig. 27, 28.*) the Power must be one fourth of the Weight, and the Celerity of the Power will be four Times greater than that of the Weight, so that for every Foot the Weight is raised, the Power must descend four Feet. And in the General, if there be ever so many Pulleys some fixed and others moveable having one common Rope, the Power must be to the Weight, as one is to twice the Number of moveable Pulleys; and the Celerity of the Power to that of the Weight will be in a like Proportion; so that if there are 3, 4, or 5 moveable Pulleys, the Power must be one sixth, one eighth, or one tenth of the Weight, and for every Foot the Weight rises, the Power will descend 6, 8 or 10 Feet; or that Length of Rope or Cord will descend, for every Foot the Weight is raised.

Fig. 29. If the Rope instead of being fixed at one End be fastened to the Weight or to the Block which supports the moveable Pulleys, so as to rise therewith, as in this Machine consisting of two moveable Pulleys; the Power will be to the Weight, as one, is to twice the Number of moveable Pulleys more by one; and the Celerity of the Power, will be to that of the Weight in a like Proportion. In this Case therefore the Power must be one fifth of the Weight, and for every Foot

Foot the Weight rises, the Power will descend five Feet.

Fig. 30. If to any of the foregoing Machines be added a Runner, that is, a single moveable Pulley which has its own Rope distinct, fixed at one End and the other fastened to a Block; the Force of the former Machines will be doubled ~~#~~ by this additional Pulley: For since the Point M moves with twice the Celerity of the Weight, as in the single moveable Pulley, and the Power with five Times the Celerity of M, then the Power will have ten Times the Celerity of the Weight, and consequently the Power will sustain twice the Weight it did before.

Fig. 31. If a Machine be combined of one fixed and several moveable Pulleys, so that every moveable Pulley has a separate Rope of its own; then, the Power will be to the Weight, as one, is to the last Term of a duple Progression whose first Term is one, and the Number of Terms one more than the Number of moveable Pulleys. Thus, in this Case, if one be added to four, the Number of moveable Pulleys; the Number of Terms in the Progression must be five: Then since one is the first Term, the last will be 16: For one doubled, will be equal to two, for the second Term; two doubled, will be equal to four, for the third Term; four doubled, will be equal to eight, for the fourth Term; and eight doubled, will be equal to sixteen for the fifth Term: So the Power will be to the Weight as one to sixteen. For the Celerity of the Power is to that wherewith the Pulley G rises, as two

to one; so likewise is the Celerity of G to that of H, as two to one; also the Celerity of H to I, and I to that of K as two to one: Wherefore if the Celerity of the last Pulley K or the Weight be one, the Celerity of I will be two, of H four, of G eight, and of the Power P sixteen.

Tho' this Engine be of greater Force than any wherein there is the same Number of moveable Pulleys, yet in as much as upon that very Account only it is that the Weights rise but slowly, it is therefore but seldom used; for Men chuse rather an Engine of two fixed, and two moveable Pulleys, with one common Rope; and if there be Occasion to double the Force, this may be done by the Addition of a Runner.

IV. Of the *Axis in Peritrochio*, or the *Axis in the Wheel*.

Fig. 32 This Engine which is a very simple one, consists of a Wheel fixed to an Axis that turns along with the Wheel; its Manner of raising Weights is thus: The Power P being applied to some Part of the Wheel's Circumference at A, turns the Wheel together with its Axis, and thereby raises one or more Weights W, W, on different Parts of the Axis; and because the Wheel A, and its Axis revolve together; in whatever Time the Power P moves through a Space equal to the Circumference of the Wheel A, the Weight must in the same Time be raised through a Space equal to the Circumference of that Part of the Axis to which the Weight is appended

appended; therefore the Celerity of the Power will be to that of the Weight, as the Circumference of the Wheel is the Circumference of the Axis; and because the Circumferences of Circles are to each other as their Diameters; the Celerity of the Power will be to that of the Weight, as the Diameter of the Wheel is to the Diameter of the Axis; if therefore the Power be to the Weight, as the Diameter of the Axis to the Diameter of the Wheel, the Power will then just sustain the Weight: Thus, if the Diameter of the Wheel be five Inches, and that of the Axis one Inch, a Power of one Ounce, or one Pound, being appended from any one Point of the Circumference of the Wheel, will support a Weight of five Ounces, or five Pounds which is appended from the Axis; and if the Diameter of the Wheel be ten Inches, and that of the Axis one Inch, then one Ounce at the Wheel, will sustain ten Ounces at the Axis.

When the parts of the Axis differ in Thickness, as B and C do; if Weights be hung at these Parts, they may be supported by one Power applied to the Wheel, provided the Product of the Power into the Diameter of the Wheel, be equal to the Sum of the Products of the several Weights, into the Diameters of the Parts of the Axis from whence they are appended: Thus, if the Diameter of the Wheel A be ten Inches, and the Power P be two Pounds, the Product will be 20; and if the Diameter of that part of the Axis B be four Inches, and the Weight W be three Pounds, the Product will be 12; and again, if the Diameter of that part of the Axis C be one Inch, and the Weight eight

H

Pounds,

Pounds, the Product will be 8 ; then the Power P will sustain the Weights W.W, in as much as the first Product 20, the Moment of the Power, is equal to the Sum of the other two Products 12 and 8, the Moments of the Weights.

This may be applied to the Machine generally used in raising Water from Wells ; for if an Handle projects five Inches from the Center of the Axis, and it be turned about, the Diameter of the Circle it describes will be ten Inches. If then the Diameter of the Axis, about which the Rope from the Bucket revolves be one Inch, then a Power of 20 Pounds at Diameter ten, will sustain a Weight of 200 Pounds at the Axis where the Diameter is one ; for 20 into 10 or 200 the Moment of the Power, is equal to 200 into 1 the Moment of the Weight.

The like may be also applied to a perpendicular Axis, with cross Bars running through it, for raising Weights from Ships, which Machine usually bears the Name of a *Crane*, and is placed on Quays where Goods are landed ; also to raise Stones for Buildings to any assigned Height, with the help of a fixed and moveable Pulley ; which Things are so frequently seen, that it is needless here to illustrate them by any Scheme or Figure ; it may be also applied to *Calanders* used in smoothing Linen, to *Windlasses* and *Capstons* in Ships, to a *Spit* for roasting Meat ; because the greater the Diameter of the Wheel the Chain is set into, be, the less Weight or Power to the Jack will be sufficient to turn the Spit, and any Meat on it : And to many other Uses of the like Nature.

V. *Of the Wedge.*

Fig. 33. In cleaving Timber with a Wedge, the Force of the Strokes on its Base AD, is looked upon as the moving Power, and the Cohesion of the Parts of the Timber, as the Resistance or Weight to be moved.

Then if the Power be to the Resistance, as half the Breadth of the Wedge is to its Side, the Power will be equal to the Resistance; and if the Power be increased it will overcome it.

From B the middle Point of the Base, let the Line BE be drawn perpendicular to the Side CD; and the Line BC the Height of the Wedge perpendicular to AD, bisecting the Angle ACD.

When the Wedge is driven into a Piece of Timber by Strokes of a Mallet from C to B, then CB will express the Celerity of the Wedge; and the Resistance of the Wood in cleaving, or the Celerity of the resisting Body on each Side of the Wedge, will be expressed by BE which is the Sine of the Angle BCE: Therefore that the Moment of the Mallet, may be equal to that of the Resistance, they must be inversely to each other as their Celerities; that is, the Power or Strokes on the Mallet, must be to that of the Resistance, Cohesion, or Texture of the Wood to be rent or cleaved, as BE to BC, that is by similar Triangles, as BD, half the Base of the Wedge is to DC the Side; or as AD is to AC and CD, or to 2 CD.

Hence it follows that similar Wedges are of equal Forces; because in these the Angle BCE remains the same, the Line BE which expresses the Resistance, being the Sine of an Angle of the same Number of Degrees will be also the same: But in dissimilar Wedges the Powers to be applied will be directly as the Sines of the Angle BCE; that is, as the Sines of the Angles BCE increase, the Forces or Powers requisite to rend the Timber with Wedges will be in the like Proportion, which may be further confirmed by the following Experiment.

If two equal Cylinders rowling on their Axes along the Edges of two horizontal Rulers, be drawn together by a Weight of 2000 Grains, which is applied to a Cord, whose Ends are fastened to the two Cylinders; then if there be three Wedges severally applied between the Cylinders each of three Inches height, with the Weight of 300 Grains appended to the first, 600 to the second, and 900 to the third, they will severally be drawn down by their respective Weights. In this Experiment the Force which unites the Cylinders, together with the Friction of their Axes are considered as the Resistance, and the Wedge with its appending Weight as the Power.

VI. Of the Screw.

The *Screw* consists of two Parts the Male and the Female, the prominent Parts of the Thread of the Male, exactly fitting the Cavities of the Female. The chief Use of this Machine is, to press

press the Parts of Bodies closely together, and sometimes to break and divide them: When it is used, one Part is frequently fixed, while the other is turned round, and of Course the Power must move quite round the Cylinder, before the Weight or Resistance ascends from one Spiral winding to another: By as much therefore as the Circumference of the Cylinder is greater than the Distance or Interval between the Spiral Lines, by just so much may the Power be less than the Weight in order to Ballance it. It therefore manifestly follows, that the greater the Circumference of the Cylinder, and the smaller the Distances of the *Helixes* or Spirals are, the greater is the Force of the Screw.

This Instrument is attended with a very considerable Friction of the Parts against one another, and it is much greater in this than in any of the other Mechanical Powers: On which Account only, the Experiments used to shew the Force of the Screw, vary more than any of the rest from the Theory.

Sometimes an Axis in Peritrochio is applied to this Instrument, upon Account of the Time lost in shifting its Handle, as well as to increase the Power.

In an Engine compounded of several of the Mechanical Powers, it will be found a Matter of no great Difficulty to compute the Force of the Whole, from the Force of every Part; if what has already been said be duly attended to; or by tracing through the Whole, the superior Degree of Celerity with which the Power moves, when compared

compared with the Weight or Resistance that is to be raised or overcome.

But in computing the Power of any Engine it must be observed, that an Allowance must be made on the Account of Friction; because no Engine can be made so perfectly smooth and exact, as to be free of it, and thereby some of its Force is lost.

From what has been said, it is plain, that the greater the Celerity of the Power be, the greater Weight it will raise, and therefore it is impossible that the same Power can raise a Weight of one Pound, and then a Weight of two Pounds, without increasing its Celerity; *And that no Engine can possibly be contrived so, as to gain Power without losing Time*: Thus it is easy by any of the foregoing Powers, to make one Person raise a Weight, equal to what 100 such Persons could jointly accomplish, but that Person must be allowed 100 Times the Time to do it.

Of Pendulums.

A Pendulum is a Weight or heavy Body hanging at the End of a String, by whose *Vibrations* or Swings, Time is measured evenly.

The small Vibrations or Arches, which are described by the same Pendulum, though they be unequal, are yet performed very nearly in the same Time: For if two Pendulums of equal Lengths, be put in Motion together at one Moment, having raised one higher than the other, before they are let go; it is plain the Arches described

described by one, will be greater than those described by the other; and yet they will be found to be described in the same Time very nearly; for in one hundred Vibrations the Difference of Time will not be one Vibration.

Fig. 34, The Times wherein Pendulums of unequal Lengths perform their Vibrations, are to one another inversely as the Square Roots of the Lengths. Thus, if the Pendulum A of 25 Inches long, and the Pendulum B of 36 Inches, be let to swing together; then A will be found to perform 6, in the same Time that B performs 5 Vibrations, these Numbers being the Square Roots of their Lengths 36 and 25. Or if the Pendulum B were 4 Times as long as the Pendulum A; A will perform 2 Vibrations in the same Time that B will perform one, these Numbers being the Square Roots of 4 and 1.

It is agreed that in our Latitude, a Pendulum of 39.2 Inches long, will in a second of Time perform one Vibration; and therefore, that a Pendulum of 9.8 Inches long, will perform two Vibrations in a second; because 39.2 is to 9.8 as 4 to 1, therefore 1 Vibration of the longer Pendulum will be performed in the same Time that the shorter performs 2.

The Length of a Pendulum is measured from the *Center of Suspension*, or Point upon which it Swings, to the Center of *Oscillation*, or to the Center or Middle of the Ball or Bob, in which Center if all the Matter of the Pendulum were collected it would Vibrate in the same Time.

The

The Time of the Vibration of a Pendulum is not altered by changing the Ball or Weight ; for it has been already shewn in *Page* 10. that light and heavy Bodies descend with equal Swiftneſs, or in the ſame Time, provided they meet with no Reſiſtance from the Air, which in heavy Bodies is very inconfiderable ; and therefore how heavy ſo ever the Weight be, the Time of a Vibration will be the ſame, while the Pendulum continues of the ſame Length : For if two unequal Weights, appended by Threads of equal Length, be let fall together from the ſame Height, they will continue to perform their Vibrations in the ſame Time.

From what has been ſaid it is plain, that becauſe one Vibration of a Pendulum of 39.2 Inches long, is performed in a Second of Time, it will be eaſy to diſcover, in what Time, any other Pendulum of a different Length will perform its Vibrations ; or if the Time be given, the Length of the Pendulum may be obtained ; but due Conſideration is to be had, that the longer Time a Pendulum takes to perform one Vibration, the fewer of ſuch Vibrations will be performed in any given Time, as in an Hour or a Minute, that is in either Caſe the Proportion will be Inverſe. Thus, if a Pendulum vibrates 30 Times in a Minute, and its Length be required ; ſay as 900 the Square of 30, is to 3600 the Square of 60, or the Square of the Number of Vibrations performed in one Minute by a Pendulum, whoſe Length is 39.2 ; ſo is that Length 39.2 to 156.8 Inches the Length of the Pendulum required. And on the contrary, if it were required to find the Number of

of Vibrations, a Pendulum of 156.8 Inches long will perform in a Minute; then 156.8 is to 39.2 as 3600 is to 900, the Square Root of which 30 will be the Number of Vibrations, a Pendulum of 156.8 Inches long will perform in a Minute. Or which is the same Thing, because first 900 is to 3600 as 1 to 4, therefore 156.8 the Length of the Pendulum, which will Vibrate 30 Times in a Minute, must be 4 Times longer than 39.2, the Length of the Pendulum that Vibrates Seconds, or 60 Times in a Minute. And secondly, because 156.8 is to 39.2, as 4 is 1, therefore the one fourth Part of 3600 or 900 must be the Square of the Number of Vibrations, which a Pendulum of 156.8 Inches long will perform in a Minute, and consequently the Number of such Vibrations will be 30.

Again, let it be required to find the Length of a Pendulum, that will Vibrate as often in a Minute, as it is Inches in Length.

The Square of 60 or 3600, the second Term being multiplied into the third Term, 39.2 will give 141120 for the Product of the Means, and as that Number therefore must be also equal to the Product of the Extreams; it follows, that because the Number of the Vibrations, of the required Pendulum in a Minute, are in this Case, equal to the Number of Inches in the Pendulum's Length, therefore, the Square of them Vibrations being multiplied into the Inches in Length, or which is the same Thing, the Cube of the Length, or of the Vibrations in a Minute, will be the Product of the Extreams, which as before, must be 141120,

or the same as that of the Means; wherefore the Cube Root 141120, which is 52, must be the Inches contained in the Length of a Pendulum, that will Vibrate 52 Times in a Minute.

Since it is well known that all Metals expand with Heat, therefore the Pendulums of Clocks become longer in Summer than in Winter, and on this account Clocks go slower in Summer than in Winter, inasmuch as the Vibrations of their Pendulums become slower, by their being lengthened by Heat: For this Reason, there is a Screw under the Bob, or Weight of every Clock Pendulum, by which Means, the Length of the Pendulum may be increased or diminished, in order to make the Clock keep due Time; that is, that the Length of the Pendulum may always be 39.2 Inches for this Latitude.

We have here said, that two Pendulums of the same Length, describing unequal Arches, will make their Vibrations nearly equal in a given Time, but not exactly so; and therefore it must follow, that because the Vibrations are not precisely equal, that such Pendulums cannot be admitted to be an accurate Division of Time, inasmuch as very small Differences will in Time amount to a sufficient large Difference, as Experience has taught us. Wherefore that the Vibrations of Pendulums may be rendered precisely equal and exact, whether the same Pendulum describes greater or less Arches, so as that Time may be measured with the utmost accuracy; Monsieur *Huygens*, discovered a Method, whereby a Pendulum by moving in the Curve of a Cycloid, will

will amply and unerringly supply whatever was before defective.

Fig. 35. If a Circle touching the right Line AB, in the Point A, be moved from A along that Line, in the Manner of a Wheel from A to B, so as to perform one entire Revolution; then the Point C will describe a Curve Line ACB, which is called the Cycloid: And a Pendulum is made to move in this Curve thus, let the *Axis* of the Cycloid which bisects the Base perpendicularly, be produced the contrary Way towards E till DE be equal to DC; through the Points A and E, and B, let two Semi-Cycloids AE, EB be drawn each equal to half ACB, their *Vertices*, or Tops being at A and B; then if EA and EB be two Plates of some Breadth, and a Pendulum of the Length of EC, appended from the Point E be made to Vibrate between these Plates; its upper Part ~~which is usually made~~ flexible, will apply itself to that Plate, towards which the Body moves, by which Means it will move in the Cycloid ACB, and measure Time equally; which has been fully proved, by the Author Monsieur *Huygens*, Dr. *Wallis*, Mr. *Cotes*, and many others.

C H A P. IV.

Of Hydrostatics or the Properties of Fluids.

HYDROSTATICS when invented by *Archimedes*, consisted only in the Art of weighing Bodies in *Water* ; but it now comprehends the Nature and Properties of *Fluids* in general.

A *Fluid* in general is a Body, whose Parts yield to the least Pressure, and in yielding are easily moved one among another.

The constituent Particles of a Fluid must be very small, hard, round and smooth ; we must grant that they are very small, because they are not to be distinguished even with the Assistance of the best Microscopes ; that they are hard, because no Fluid is compressible, or can possibly be pressed together into a less Space, than that which it naturally possesseth ; (except Air or Steam, of which hereafter) and that they must be round and smooth, because the Particles or Parts, easily yield to any impressed Force or pressure.

It is most certain, that Fluids as well as Solids consist of heavy Particles, whose Gravity is ever proportionable to the Quantity of Matter which they contain ; and therefore it follows, that the Surface of a Fluid will be smooth and level, if it be not actuated on by some extraneous Cause ; for
should

should any Part be higher than the rest, it must descend by the Force of Gravity, and so spread itself till it comes on a Level with the rest; or Physically speaking, till it partakes of the Earth's Rotundity.

Fig. 36. The Force of Gravity, likewise occasions the lower Parts of Fluids, to be pressed with a Force that is proportionable to their perpendicular Height from the Surface: For, suppose the Fluid in the Vessel AE, to be divided into several equal Parts, by the Lines A,B,C,D,E; then it is plain, that the lowest Part, or that under the Line E, must sustain a Pressure of all those Parts which are over it, and that the Parts D or C, will also be pressed by those Parts which are above them; and therefore any Part of the Fluid, or any Body which is immersed in any Part of the Fluid, will sustain a Pressure which will be greater or less, as its Distance is from the Surface, or a Pressure which will be proportionable to its perpendicular Height from the Surface. Thus an empty Bottle, being close corked up, and sunk to a great Depth in the Sea, will either be pressed together by the Force of the incumbent Water, or will have its Cork thrust into it. Which Experiment is well known to Sea-Men.

Since therefore the Parts of a Fluid which are at equal Depths below the Surface, are equally pressed, they must consequently be at rest, and not in continual Motion, as some would have it: But when this equality of Pressure is destroyed, then it is plain, a Motion will arise in the Parts
of

of the Fluid, which will continue till the Pressure becomes again equal.

The Force wherewith the lower Parts of a Fluid are pressed downward, exerts itself equally in all Manner of Directions; *Fig. 36*, For if an Orifice be made at *s* in the Side of a Vessel containing any Fluid, the Fluid will rush out with the very same Velocity, as if it run through a like Orifice made at *b* in the Bottom, because it will be Discharged through either in the same Time: And in like Manner, a Fluid will press upwards with an equal Force; for if a Tube as *z* be turned upwards, the Fluid will spout from it almost as high as the Surface thereof in the Vessel, and would quite as high if it were not for the Resistance of the Air, and the Friction of the Water in the Pipe or Tube.

Fig. 37. The upward Pressure of Fluids may be also demonstrated thus: Take a smooth Weight as a Piece of Lead, and fitting it to the End of a Tube, with a wet Leather between them; hold the Weight by a String, passing through its Center of Gravity, keeping the Tube close thereto, and immerse it to the Depth of 12 Times its own Thickness, or more, in Water; (for Lead is above 11 Times heavier than Water); If then you let the String go, the Pressure of the Water upwards against the Weight, will Support and keep it to the Tube, because the downward Pressure is taken off by the Tube.

Or thus; If a Piece of Paper, be put over the Mouth of a Glass full of Water, and the Glass be carefully turned with the Mouth downward, the Water will remain suspended in the Glass by the Atmosphere

Atmosphere, or Air pressing upwards, because its downward Pressure is taken off by the Glass.

The Pressure which the Bottom of a Vessel sustains from a Fluid contained therein, is as the perpendicular Height of the Fluid only, and not as the Quantity of Fluid the Vessel contains.

Thus, *Fig. 38*, If an unequal bended Tube ABC, having its open Ends A and C turned upward, has Water poured in at either the smaller End A, or at the wider End C, it will rise to an equal Height in each Leg; and therefore the lateral or side Pressure next the Bottom B, must be manifestly the same from each: But because, the Pressure of a Fluid on the Bottom of a Vessel has been shewn to be equal to the lateral Pressure, therefore the Bottom of the Vessel is equally pressed by the Fluid in the smaller Leg, and by that in the greater One, or as the perpendicular Height of the Fluid in each Leg, and not as the Quantity contained in each.

Hence arises this *Hydrostatical Paradox*, that a small Quantity of a Fluid may be made to press as much, as any other Quantity how great soever; for if the Leg CB be increased to a Size however great, and the Leg AC be diminished as small as may be, or if the Quantity of Fluid contained in each, be according to any assigned Proportion whatsoever, the Pressures at the Bottom will be equal, for the perpendicular Heights of the Fluid in each Leg will be the same.

Fig. 39. Let there be two Vessels A and B filled with Water, whose Bottoms CD and EF are equal, but the Capacities of the Vessels as different

as may be; if an equal Hole be bored in the Bottom of each, and the Vessels be kept constantly filled to the same Height, the Water will be found to run with an equal Celerity from each; and therefore the Pressure of the Fluid against the Bottom of each will be equal, so long as the perpendicular Height of the Water remains the same. It therefore evidently follows, that the Banks of the Sea are no more pressed, than those of a Pond or of a Ditch of equal Depth, abstracted of the Force of the Waves, and of the Difference of Weight between Salt and Fresh Water.

From what has been now said it is evident, that the Pressures on equal Bases are as the perpendicular Heights of the Fluids contain'd in them however different the Vessels themselves be: And universally that the Pressure on any Base is measured, by multiplying the *Area* of the Base, into the perpendicular Height of the Fluid, without regarding the Quantity of the Fluid. Thus if two Vessels of equal Bases, have 5 Inches depth of Fluid in the one, and 4 in the other; the Pressure on the Base of the first, will be to that of the second, as 5 to 4: Again, if there be the Bases of two Vessels, whose Areas are as 4 to 1; and if the Depth of the Fluid in the first be 8 Inches, and that of the second 32; then 4 multiplied by 8 or 32, will Measure the Pressure on the whole Bottom of the first, and 1 multiplied by 32, or 32, will Measure the whole Pressure on the second; and seeing these Measures are equal, the whole Bottom of the first will be pressed with a Weight, equal to
that

that which presses the whole Bottom of the second. But when we say, Fluids press with a Force, which is proportionable their perpendicular Heights, we mean that they press in that Proportion, supposing their Bases equal, or that they press in that Proportion upon any equal Parts of the Bottoms or Sides of Vessels, when their Bottoms are unequal.

Since the Bottom of a Vessel, bears a Pressure proportionable to the Height of the Fluid, and that those Parts of the Sides which are adjacent to the Bottom, bear a like Proportion, it therefore follows, that if a Hogshead full of Liquor be set on an End, the Sides next the Bottom will bear the greatest Stress, and that the stress decreases, just as the Distance from the Bottom increases; for which Reason it is fit, that Vessels of a considerable Height, should be much stronger at the lower, than at the upper Parts, in order that they may be enabled to sustain the Pressure.

The Pressure on the Base, being as the Height of a Fluid, it is easy to conceive, that if a full Hogshead be set on an End, and a Pipe be inserted through a Hole made in the upper End, and filled with a like Fluid, the Bottom will be as strongly pressed, and be in the same Danger of Bursting, as if the Hogshead was continued to the same Height as the Pipe, and filled with Liquor; and that if such a Pipe were continued to a great Height and filled, no Hogshead would be sufficient to withstand the Pressure.

Of the Specific Gravities of Bodies.

The *Specific Gravities* of Bodies, are the Weights of Bodies of the same Size or Bulk when compared to each other ; thus if a Cubic Inch of one Body be 2 or 3 Ounces, and a Cubic Inch of another Body weighs one Ounce, then the first Body is said to contain two or three Times the Specific Gravity of the other, or to be two or three Times Specifically heavier than the other.

The *Relative Weight* or Gravity of a Body, is the Excess of it's Specific Gravity, above that of a Fluid, in which it is immerfed.

Fig. 40. A Body Specifically heavier than a Fluid when weighed therein, looses so much of its Weight, as is equal to the Weight or Quantity of that Fluid as big as the Body : For, let the Body B be immerfed in the Vessel A, filled with Water, it will throw out of A into the Vessel CC, wherein it is immerfed, just so much Water as is equal to the Bulk of the said Body B.

Hence if a Body be weighed in Water, and out of it, the Difference of Weights, will be the Weight of a Quantity of Water as big as the Body : And if the absolute Weight of the Body, or it's Weight out of the Water, be divided by the said Difference, the Quotient will shew how much heavier than Water that Body is.

After this Manner the Specific Gravities of Bodies may be found. Thus, If a Quantity of Mercury Weigh 84 Grains out of Water, and 78 Grains in Water, the Difference of these Weights,

6 Grains

6 Grains is the Weight of as much Water, as is equal in Bulk to the Mercury; if then 84 Grains, the absolute Weight of the Mercury, be divided by the aforesaid Difference 6, the Quotient 14 shews, that Mercury is specifically heavier than Water.

By this Method, the Specific Gravities of several Bodies are found, that is how many Times they are heavier than Water, Bulk for Bulk; as in this Table.

A Table shewing the specific Gravities of certain natural Bodies.

The finest Gold	-	-	19.640
Standard Gold of <i>England</i>	-	-	18.888
Mercury	-	-	14.000
Lead	-	-	11.325
Fine Silver	-	-	11.091
Standard Silver	-	-	10.535
Copper	-	-	9.000
Cast Brass	-	-	8.500
Steel	-	-	7.852
Iron	-	-	7.643
A Diamond	-	-	3.400
Clear Glass	-	-	3.150
Green Glass	-	-	2.620
Dry Ivory	-	-	1.825
Ebony	-	-	1.177
Human Blood	-	-	1.054
Cows Milk	-	-	1.030
Sea Water	-	-	1.030
Common Water	-	-	1.000

Dry Oak	-	-	-	925
Spirit of Wine	-	:	-	866
Cork	-	-	-	240

The specific Gravities of solid as well as fluid Bodies, are different from one another in Summer and Winter. For in Summer all Things are rarified by the Sun's Heat, and in Winter they are condensed by the Cold. Yet this Rarefaction or Condensation is not alike in all Bodies, but very different, as will appear by the following Table, which shews the Weight of a Cubical Inch of *Paris*, there in Use.

	In SUMMER.			In WINTER.		
	Oz.	Dr.	Gr.	Oz.	Dr.	Gr.
Mercury	7	1	66	7	2	14
Oil of Vitroil	0	7	59	0	7	71
Spirit of Vitrol	0	5	33	0	5	38
Spirit of Nitre	0	6	24	0	6	44
Spirit of Salt	0	5	49	0	5	55
Aqua-fortis	0	6	25	0	6	35
Vinegar	0	5	15	0	5	21
Vinegar distilled	0	5	11	0	5	15
Spirits of Wine	0	4	32	0	4	42
Cowes Milk	0	5	20	0	5	25
River Water	0	5	10	0	5	13
Well Water	0	5	11	0	5	14
Water distilled	0	5	8	0	5	11

In the first Table, if the Point be taken from the Numbers, or which is the same Thing if each Number be multiplied by 1000, you will have

have the Ounces Avoirdupois which are contained in a Cubic Foot of each Body.

By this Table may be found the different Quantities of two Metals, which Metals are known to compose a Body however great or small.

Find the Specific Gravity of the Mixture, or how many Times it is heavier than Water, as before: Then subtract the Specific Gravity of the lighter Metal, found by the Table, from the Mixture, and that of the Mixture from the heavier; the first Remainder will shew the Bulk of the Heavier, and the latter the Bulk of the Lighter. If these Remainders be multiplied by their respective Specific Gravities, the Products will shew the Proportion of the Weights of each Metal of the Mixture. Thus;

Suppose there be a Body weighing 30 Grains, which I know to be a Composition of two Metals, as of the finest Gold and Copper, and that I find as before the Specific Gravity of the Mixture to be 13, or that it is 13 Times heavier than Water. Required how much of the finest Gold, and how much Copper there is in the Mixture.

From the Specific Gravity of the Body	13
Take the Specific Gravity of the	} 9
Copper as in the Table - - -	

There remains the Bulk of the finest Gold 4

From the Specific Gravity of finest } 19. 64
 Gold in the Table - - - }

Take the Specific Gravity of the Body 13.

There remains the Bulk of Copper 6. 64

Then finest Gold	19. 64	And Copper	9.
Mul. by	4.	Mul. by	6. 64

The Prop . of Gold	<u>78. 56</u>	Prop. of Cop.	<u>59. 78</u>
--------------------	---------------	---------------	---------------

So that for every 78.56 Pounds, Ounces, or Grains of the finest Gold, there will be 59.76 Pounds, Ounces, or Grains of Copper in such a Mixture.

Let these Numbers be added together
 Gr.

78.56

59.76

138.32 whole Mixture

	Gr. Mix.	Gr. Gold	Gr. Mix.	Gr. Gold
Then say, as	138.32	: 78.56	:: 30	: 17
		Gr. Cop.		Gr. Cop.
	138.32	: 59.76	:: 30	: 13

So that the Body contains 17 Grains of finest Gold, and 13 Grains of Copper.

N. B. This Process is only inserted for the Use of Beginners.

Fig. 41. A Body specifically lighter than a Fluid will swim thereon, in such a Manner, that a Quantity of that Fluid equal in Bulk with the immersed Part of the Body, will be as heavy as the whole Body.

Let the Body B be put into a Vessel A filled with Water; it will throw out of the Vessel A into the Vessel CC in which it is placed, just so much Water as will be equal in Bulk to the Part immersed, and the Water so thrown out of the Vessel A, will be exactly equal in Weight to the whole Body.

Hence the lighter a Fluid is, the deeper a Body will sink in it, upon which depends

The Use of the Hydrometer or Water-poise.

The *Hydrometer* is an hollow Glass or Ivory Ball with a small hollow Stem of about 5 or 6 Inches long, opposite to which on the other Side of the Ball adheres a smaller Ball which is partly filled with Mercury, in Order to keep the Stem perpendicular to the Fluid in which the Balls and Part of the Stem are immersed.

Fig. 42. The Use of this Machine is to discover the Specific Gravities of Fluids, and this is done by first setting it to float in one Fluid, and observing the Degree cut by the Fluid on the graduated Stem which is Marked and Numbered; and then by putting it in any other Fluid and observing the Number on the Stem cut by the Fluid, and this last Number will be to the former

mer, as the Specific Gravity of the first is to that of the last Fluid: Thus,

The Hydrometer being put into Water sinks to the Number 87, and being put into Spirit of Wine sinks to 100: Whence the Specific Gravity of Water is to that of Spirit of Wine, as 100 is to 87.

Hydrometers made of Ivory are better than those of Glass, for if the Stem be Glass the Fluid will rise about it from its attractive Force, and give a greater Number than it should.

The Flux of Water from Reservoirs through Orifices and Pipes.

If Water flows through an Orifice in the Bottom of a Vessel which is kept constantly full, or to the same Height; the Velocity with which it flows out, is as the Square Root of its Height above the Orifice.

Fig. 43. Let there be two Vessels alike in all Things, except that one is four Times as tall as the other, or let the Height of A be 20, and that of B 5, each having a Circular Orifice of $\frac{1}{4}$ Part of an Inch in the Bottom. If these Vessels be filled with Water and set running, the Water being constantly supplied above as fast as it runs out below; the taller Vessel will discharge 21 Ounces in a Quarter of a Minuet, and the latter 11 Ounces: Therefore the Velocity with which the Water flows out of the taller Vessel, is to the Velocity wherewith it flows out of the shorter, as 21 is to 11, that is as 2 to 1 nearly; which
Numbers

Numbers are the Square Roots of 4 and 1, which express the Proportion of the Heights of the Water above the Orifices.

Hence if an Orifice in the Side of a Vessel, be placed as much above an horizontal Plane, as the Surface of the Water is above it; the Water will Spout to twice the Distance, that the Orifice is above the Plane.

Fig. 44. Let two Vessels A and B be full, and let A be set upon a Plane equal to its Height, and the Orifice made in its Side next the Bottom; and let the Orifice in B be in the Middle of the Side: Then the first will be found to Spout to the Length of the Vessel and Stand, and the other to the Length of the Vessel.

The Distance to which Water spouts from an Orifice in any Part of the Side of a Vessel, will be twice the Sine made from the Orifice, to a Circle described from the Top of the Water to the Bottom of the Vessel. Thus, *Fig 45.*

Let a Vessel filled to 16 Inches, and supplied to that Height be perforated in the Middle at A, and towards either End at B and C, five Inches above and below the Middle. From the Top of the Water to the Bottom, let the Semi-Circle be described, and from the Orifices C, A, B, let the Perpendiculars, or Sines BF, AE, CD be drawn: Then the Water will Spout from the several Orifices, to twice the Distance of these Sines, that from A will be found to Spout more than 15 Inches, and the Spouts from B or C will be 11 Inches.

The Velocity wherewith Water flows out of a Cylindrical Pipe inserted horizontally in the Side of a Vessel, is as the Square Root of the Height of the Water, above the Place of the Pipe's Insertion directly, and the Square Root of the Length of the Pipe inversely. For the Place of the Orifice may be looked on as if it were in the Bottom of the Vessel, since no Water under it can flow out; and the same Velocity wherewith the Water flows out of the Cylindrical Pipe, with the very same Velocity it flows in it, at the other End, that is, it will be as the Square Root of the Height of the Water above the Orifice: But the Water in the Pipe becomes a Clog, and impedes the Velocity rushing in at the Pipe, and the longer this Pipe is, the greater the Impediment will grow, and of Course the less will be the Velocity of the Water in the Pipe; and this is found to be Inversely as the Square Root of the Pipe's Length: For if a Pipe that is 16 Feet long, and half an Inch Diameter, be inserted horizontally in the Side of a Vessel, and the Water in the Vessel be kept constantly 3 Feet above the Orifice, this Pipe will Discharge $161\frac{1}{2}$ Ounces in half a Minute: Let the Pipe be then shortened, so as to be only 4 Feet in Length, and set a running, it will then Discharge 321 Ounces in half a Minute, which is near twice as much as it did before; so that the Quantities discharged will be to one another Inversely, as the Square Roots of the Pipe, which in this Case is as 4 to 2, or as 2 to 1.

Having

Having thus far given some of the general Properties of Fluids, it will not here be amiss, if we inquire into the Nature and Use

Of Water.

1. Water affords Drink to all Animals, for it is impossible to prepare any Drink, that is necessary for Life and Health, of which the greatest Part is not Water.

2. It dissolves Meat in our Mouths, and occasions all Tastes to be perceived by Animals..

3. It is the Vehicle of all Animal Nutriment, to the respective Parts of the whole Body.

4. It is the Cause of Life, since by diluting the Blood, it affords it an easy and free Passage through the Vessels.

5. It is the Cause of Vegetation, and of the Growth of Vegetables.

6. If Water were not by some Means conducted into the Bowels of the Earth, Fossils could not grow. For it produces a petrifying Juice when mixed with the Earth, which applying to other Earths is converted into Stones and Flints.

7. It is the Vehicle of Fishes.

8. It is the Vehicle of Ships, by which Merchandize is extended to the most remote Nations.

9. It forms Rain, which by its Descent purifies the Air, and Washes away all Kind of Filthiness and Impurity.

10. It is the sole Cause of Springs and Rivers ; it is of Use in moving Mills, and for innumerable other Uses.

Water

Water is Fluid, Liquid, Humid, Insipid, without Smell, Limpid, Lucid, without Colour, Volatile by a small Heat, it will not burn in Fire, but on the contrary extinguishes it; and therefore it is easily distinguished from all other Fluids.

The Species of Waters are reduced to Six.
1. That which falls in Rain, Hail, or Snow.
2. Spring-Water. 3. River-Water. 4. Well-Water. 5. Lake-Water. 6. Sea-Water. And of these severally.

Rain, Hail, and Snow, were originally Water which was exhaled from the Surface of the Earth, in the form of Vapour, and composed Clouds, from whence it fell upon the Earth; which shall be hereafter more fully explained.

These airy Exhalations or Vapours being received by the Earth, penetrate therein according to its various Circumstances. Some of these Waters sink to the deepest Places, and if they can burst forth they constitute Springs, which throw out Waters higher or lower, according to the different Altitudes of the Sources which collect them.

Rains and Springs flowing along the Earth's Surface to low and hollow Places, constitute Rivers.

If we dig into the Earth to any considerable Depth, we find a Bed of Sand, that affords plentiful Veins of Water, which ouze through the Interstices of the Sand into the Bottom of the Hole or Well, and by this Means we are supplied with what is called Well-Water.

Lake-Water is composed of Rain, Springs, and sometimes with Rivers.

And

And Sea-Water is Salt and Bitter, and constitutes the Ocean.

Natural Water is seldom pure, being corrupted by the subtile Particles of the Earth. For Rain in its Passage through the Earth washes it, and carries with it the Seeds of the most tender Plants, Animalcula which swim in Air, Volatile aerial Salts, subtile Earths, and many other Things which float in the Air. And according as Water runs through different Earths, Salts, Vitriols, Metals, Sulphurs, Soaps, &c. they are known by different Names, as Sulpherous, Chalybeate, Aluminous. In Spaw-Waters are found Chalk, Ocre, Brass, Sulphur, Vitriol, Nitre, Lead, Cerus. In the *Bath-Waters* of *England*, were found in the Quantity of one Barrel, 5 Ounces and 3 Drachms of Stone, 2 Ounces and a Drachm and a half of blue fulpherous Earth, and 3 Ounces of Salt, as well Sea-Salt as of Nitre. In the *Pymont-Waters* there is much bitter Salt, Iron, and gravelly Earth.

Hence according to its various Ingredients it produces different Effects. There are Waters near *St. Baldomar*, in the Province of *Lionnois* in *France*, and near *Valentiola* in the Kingdom of *Toledo* in *Spain*, which abound with an intoxicating Spirit, as strong as Wine. Others are of a poisonous Quality, as a Fountain called *Styx*, near *Nonacris* in *Arcadia*, which deceives and kills Strangers, as no Suspicion can arise either from its Appearance or Smell. There are many Kinds of noxious Waters, which cause scrophilous Disorders, and others which loosen Men's Teeth. But the In-
gredients

gredients through which such Waters pass, are the Cause of these bad Effects, and not the Water only.

Well-Water that flows through small Flints, or a Bed of fine Sand is very pure; but otherwise it is infected with the same Terrestrial Parts as Spring-Water. Lake and River-Waters are impure, as they contain Mud, Filth, Plants, Fishes, and whatever else the Wind, the Air, Men, or Animals cast into them. Sea-Water contains not only Salt, but Bitumens, and all Kinds of Filthiness, because Rivers discharge themselves into it. Sea-water therefore is not only salt but has a particular Bitterness which arises from the Bitumen that flows out of Submarine-springs, as also from the Oils of Plants, Animals, and the nitrous Salts. The Salt that is in Sea-water at the Depth of six Inches from the Surface, is of a different Temper than that which is taken at greater Depths. For if the first Salt be laid upon blue Paper, it makes it red like Nitre, which does not happen from the deeper Salt.

Some learned Men have thought, that the bitter Sea-salt is volatile, and is by that Means dispersed through the Atmosphere, and that it is the Mother of natural Vitriol, Alum, Nitre, Ammoniac. This Bitumen seems to be the Cause why Sea-water shines in the dark, when dashed against hard Bodies.

Sea-water is purified by passing through very fine Sand gathered in deep Vessels and heaped upon one another, for thereby it looses its bitterness and unsavory Taste, and becomes mere Water.

And

And hence it is that Wells dug upon a sandy Sea-shore afford sweet Water.

This may be also performed by certain porous Stones, yet thereby the Sea-water will not be quite freed of its bitterness.

Dr. *Lister* informs us that Sea-water may be purified by Means of the Alga or Sea-weed, that suddenly perspires the Water.

Deslandes made Funnels of Virgin's-wax, which being filled with Sea-water, it became sweet. And *Luetman* let Sea-water pass through soaking Paper, which he afterwards suffered to Putrify, and whatever Salts are in it, become volitile and fly off, and the terrestrial Parts remain behind: Again he passes the Water he received through the soaking Paper, through other Paper of the like Kind, and this he affirms is purer than distilled Water, because the Salts and Earths are now taken away. This Method is recommended by *John Gadesten* AN. 1516, as Dr. *Hales* relates.

Sea-water is best purged from its Impurities when it is resolved into Vapours, either by the Sun, or by culinary Heat. Therefore Rain thus becomes pure, though it be formed of Water out of the Ocean, of Lakes, of Rivers, and of many different Exhalations from several Bodies on the Earth's Surface. For pure Water is easily raised into Vapours by a slender Heat of the Sun, whereas the Salts and other grosser Parts are raised with much more difficulty. The *Egyptians* being sensible of this, drew their Water by Night out of the *Nile*, before the Sun had exhaled the more subtile Parts. If Sailors by Night draw Fleeces
of

of Wool over the Deck and Sides of a Ship when they are in the midst of the Ocean, they in the Morning may squeeze fresh Water thereout fit to drink: But the purest Water of all is made by repeated Distillation, which leaves the unwholesome Dregs remaining in the Vessel; and it will be more perfect and pure if the Distillation be made from Rain Water, or from Snow gathered in a clean and deep Place, and but little defiled by the Air: Yet notwithstanding all that has been said, any of those Waters however well purged, will have both a Taste and Smell, which is not as grateful as common fresh Water.

Mankind have taken uncommon Pains to render Salt-water fresh for the Use of distressed Mariners; and for this End have suffered it to putrify. Now when it is in a State of Putrefaction, if it be distilled to half, it will stink most offensively, but the next Day the Residue, or what remains is sweet and clear, as all the Dirt and Filth is left behind. If the Sea-water be completely Putrified, the Water of itself becomes sweet and limpid; and then Part of it may be distilled, but not all, because the Spirit of the Sea-salt remains at the Bottom, which would ascend were the whole distilled; and that distilled Water will still have an urinous Smell, though it be fresh and pretty pure, and will be of a brown Colour, and have a Sediment like some Well-waters; but this Smell goes off in Time, and it serves very well for boiling Pease, making Burgoe, Broth, and for many other Uses on board of Ships.

The

The Putrefaction of Sea-Water is increased by adding Ising-Glass to it. The greater the Putrefaction be, the more wholesome the Distillation, produced from it will be, which have occasioned some to add the *Lixivium* of the Salt of Tartar, and then to have it Distilled again; others have added Salt of Tartar, Lime, Bones, and calcined Shells of Oysters, and then have Distilled it again, though with less Success than the former.

Some by impregnating a glutinous Mixture, as Whites of Eggs, Milk, Ising-Glass, and other like Things, have made Water purer by the Gluten imbibing the Impurities; but even by this Method, Sea-Water will still have a disagreeable Taste, which common Fresh-Water has not.

Others have mixed Crude Tartar in Salt-Water in order to absorb the Sea-Salt; again Oil of Tartar has been poured into Sea-Water to precipitate the Sea-Salts with it, and then they distill the Water and strain it. *Glauber* imagined that Lapis Specularis would answer this Purpose when reduced to Powder. And others have added acid Spirits yet with the help of all these Things, they could never freshen Sea-water so as to make it fit for Man's Use, for some Salt and some Bitterness still remained. Dr. *Hales* has gone far beyond others in Trials of this Kind.

The purest Water is thus known. 1. If it be clear and transparent without any Colour, Taste or Smell. 2. If when a Solution of Silver in Spirit of Nitre is put to it, the Water continues

limpid as before, otherwise it will be turbid and bluish. 3. If it will not look like Milk though Oil of Tartar be pounded in it. 4. if it does not become thick by the Infusion of a Solution of Sugar of Lead. Lastly if *Venetian Soap* be equally dissolved by the Water without leaving any Fragments behind.

Mr. *Richard Cunningham* Chemist, exhibited two Processes in the Laboratory of the College of *Dublin*, on the 6th Day of August 1754 for rendering Sea-water fresh and potable, so as to be useful at Sea. The Salt-water was taken up in *Dublin Bay* between *Dunlary* and the *Head of Howth*. The first Process was according to Mr. *Appleton's* Method which was lately discovered, and the other according to Mr. *Cunningham's* own Invention; and after trying several Experiments on the Purity and Freshness of the said Waters it was found, that the Water purified by Mr. *Cunningham's* Method was preferable to that done by Mr. *Appleton's*. For Dr. *Rutty* tells us that Mr. *Cunningham's* Water continued exquisitely clear, without forming the least Cloud or Opacity with the Solution of Silver, or with the Solution of Sugar of Lead, and that Mr. *Appleton's* did not.

Mr. *Cunningham* informed Dr. *Edward Barry*, Dr. *Ferral*, Mr. *Croker* Chemist to the College, *William Maple*, and *John Putland Esqrs*; before whom he performed several Processes, that the Ingredients he used, are cheaper and less troublesome than those made Use of by Mr. *Appleton*.

Rain

Rain, Well, or River Water being filled in Casks to carry to Sea, will be changed in the Colour, Taste and Smell, so that it becomes nauseous and stinking, and not easily drinkable for Seamen. This Change is made by little Insects which floating in the Water soon become a Multitude; if this stinking Water boils upon a Fire, the Animalcula die immediately, and with the other Filth subside or sink to the Bottom.

Many have endeavoured to preserve Water from Insects and Putrefaction by mixing with the Water such Bodies as kill the Insects; yet this Mixture, though it answers that End, is destructive and injurious to the Health of Man. The diligent Dr. *Hales* found by repeated Experience, that an Ounce of Oil of Sulphur, or Eight Scruples of the Oil of Vitriol, are sufficient for every Butt of Water. If Butts are smoked with the Fumes of burning Brimstone, before they are filled with Water, it will be a great Means of preventing the Increase of the Animalcula, or of preventing the Water of being so horribly nauseous as it otherwise would be.

Pure-water being closed up in a Vessel of Gold, Silver, Lead, or Pewter, whether infected by Air or purged from it at a cold Season, being pressed by a Screw or struck with a Hammer cannot be condensed into a less Space than is the Capacity of the Vessel which contains it, as many Philosophers have proved by Experiments. The Water will transude or glide through the Pores of the Metal which compose the Vessel, and on its Surface will lie like Dew all around; so that

by as much as the Cavity becomes greater by the external Pressure or Force, by so much exactly will the Water perspire through the Metallic Pores; as may be seen by striking a Hammer against a Globe or Ball filled with Water, for at every Stroke the Water will ouze out.

The Particles of Water are hence very hard as was said before; and therefore they do not easily change their Figure, nor do they fill their own Pores or Interstices between them.

Hence also, a flat Board may be as easily broke by striking the flat Side against Water, as if it had struck against a hard Body. And Leaden Balls fired from a Gun obliquely against Water become as flat, as if they had struck against Stones; nay they sometimes break to Pieces. Therefore if a Glass Vessel be completely filled with Water, and its Mouth be closely shut with a Cork; if the Cork which we here suppose to touch the Water be forced in farther, the Vessel will break.

Hence we may learn, that it is convenient that Bungs of Casks or Corks of Vessels should not touch the Fluids they contain: For if they do, it is odds that the Vessels be not broken if transported to a greater Degree of Heat; provided the Bungs or Corks stand; and if the Vessels be not broke, the Bungs or Corks will fly out.

C H A P. V.

Of Pneumatics or the Properties of Air.

AIR is a very thin elastic Fluid which surrounds the Globe of the Earth. It is a difficult Matter to ascertain the Nature and Origin of Air, as it is an imperceptable Fluid to all our Senses, except that of Feeling. From the Impression and Resistance it makes, we know there is such a Body, which every where surrounds us, and is of the utmost Importance to Mankind.

Mr. *Boyle* gives us the best Account we have of its Origin. He supposes it to consist of three different Kinds of Corpuscles, viz. 1. Of Numberless minute Particles, which in the Form of Vapours or Exhalations ascend from the Earth, Water, Vegetables, Animals, &c. in short of almost all Substances on the Earth's Surface or very near it. 2. Of still a more subtile Matter, consisting of infinitely small Atoms, occasioned by the Magnetical Effluvia of the Earth, and other most minute Particles, sent with the Light which issues from the Celestial Luminaries, occasioning thereby the Idea of Light in us. 3. Of an elastic Substance which is the Basis of the other Parts, and constitutes the Essence of Air, concerning the Structure of which various Hypotheses have been framed.

Some

Some have compared the elastic Particles to the Springs of Watches coild up, and endeavouring to restore or expand themselves; others to compressed Wool which expands it self when the Pressure is taken off; and others, to slender Wires of different springy Consistances, and Substances, which will admit of Compression and Expansion, yet in the whole all amount to one and the same Thing.

Before we proceed to explain the Properties of the Air, it will be necessary to describe the *Air-pump*.

The Air-pump is a Machine by which the Air contained in a proper Vessel, may be exhausted or drawn out.

Otto de Guerick a Burgo-master of *Magdeburg* was the first Inventor of this curious Instrument; which was afterwards very greatly improved by Mr. Boyle, Mr. Papin, and Mr. Hawksbee.

The common Air-pump is represented in the *Figure fronting the Title Page*, where AA, are the two Brass Barrels, in which the Pistons CC move up and down. The Brass Tube or Pipe marked HH is called the Swans-neck, through which the Air passes under the Receiver OO, by a small Hole K, in the Middle of the Brass-plate II on the Top of the Pump, to a Brass-piece in the Box DD; which being perforated lengthways to the Middle Point under the Barrel, transmits the Air to a Bladder-valve to be pumped out. The Mercurial Gauge which communicates with the Receiver or Glass Vessel on the Top is marked LLL.

LLL. The Stop-cock N, serves to readmit the Air when there is Occasion. B is the Handle or Winch for working the Pump. GG, are two Pillars supporting the Frame of the Pump-wheel, which is screwed upon them by the two Nuts EE. As to the Uses of the other Parts, they will easily be comprehended by inspecting the Figure.

The Operation of this Machine depends on the Elasticity or springing Force of the Air: For by working the Pump, the Air in the Receiver will expand it self; by which Means Part of it will be forced into the Barrel of the Pump, to be carried off. By thus continuing to work the Pump, the Air in the Receiver will be gradually exhausted, but can never be wholly drawn out so as to leave a perfect Vacuum under the Vessel.

We now proceed to explain the Properties of Air, and

I. *That Air is heavy.*

This will evidently appear to be true from the following Experiments.

Let a Glass Bottle, to which there is a Brass-neck with a Cock therein that opens and shuts, be screwed into the Plate of an Air-pump and the Cock left open, have the Air exhausted from it by Pumping, and the Cock then closed to prevent any Air from rushing into the Bottle; if then the Bottle be unscrewed from the Pump, and appended at one End of a Ballance, with a Weight just sufficient to sustain it at the other
End

End, has its Cock then opened, the Air will rush into the Bottle, and the Bottle will descend. If it be one that contains about 40 Cubic Inches, it will require 10 Grains to restore an Equilibrium; so that 40 Cubic Inches of Air, are equal in Weight to 10 Grains; and thus the Weight of a Cubic Foot of Air has been found, and discovered to be 850 Times less than a Cubic Foot of Water.

Let a Brass or Copper Rim be covered over one End with a Wet Bladder well stretched and closely bound round the Rim by a Thread or String, have the open End of the Rim laid on the Pump; upon exhausting the Air from within Side of the Rim, the Bladder will be found to be pressed downwards by the incumbent Weight of the Atmosphere more and more as the Pump is kept working, till at length the Bladder is broken, and a loud Report is produced by the Air's rushing in to fill the Vacuity.

Let a thin square Glass Vial being close corked up, having a very small Orifice made quite through the Cork, be placed on an Air-pump under a Receiver: Upon exhausting the Air from under the Receiver, the Air will also be exhausted from the Vial through the Orifice: If the stop Cock be then opened and the Air readmitted, it will rush with such Violence on the Vial, as to break it to Pieces; because a sufficient Quantity of Air cannot rush through the Orifice made in the Cork of the Vial, in a Moment, to enable it to withstand the outward Pressure.

Let

Let a Glass Vessel, part filled with Mercury or any other Fluid, be placed on the Pump under a Receiver; and let a Tube closed at one End and open at the other be inserted through an Orifice in a Collar on the Top of the Receiver with wet Leather about it, so as that the open End may not reach the Mercury in the Glass Vessel: The Receiver being then exhausted of Air, the Tube will be also exhausted: Let the Tube be then pushed down gently into the Mercury in the Glass Vessel, and the Air readmitted into the Receiver, it will then be found to press so heavily on the Mercury in the Glass Vessel as to drive it up the exhausted Tube, untill the Weight of the elevated Mercury presses as forceably against that Part which is immediately under the Tube, as the Weight of the Air does on every other equal Part which is without the Tube.

Fig. 46. By the Weight and Pressure of the Air, Water is raised in Pumps, and Fire Engines, thus. Let AB represent a Pump, or Tube open at both Ends, C a fixed Plug with a Hole through its Middle, covered with a Leather *Valve* like a Trap Door, that will easily open to let the Water pass upwards, and shut to prevent the Water passing downwards: D a moveable Plug, *Piston*, or *Sucker* made in all Respects as the former, but joined to the Rod E, and that Rod to the Handle that works it. The Sides of the Piston are cased with Leather to fit the Cavity of the Pump so tight that neither Air or Water can pass between. At some Distance above the

N
Piston

Piston is an Orifice at O in the Side of the Pump through which the Water is discharged in the following Manner. The Piston D being drawn up, driving the Air before it, thereby causes a *Vacuum* between C and D; and the Air pressing on the Water in the Well, drives it through the Plug C whose Valve opens to let it through, to fill up the Vacuity; then upon depressing the Piston D, the Valve of C shuts and prevents the Water to return downwards, and immediately it rises through the Piston D whose Valve opens, and lodges itself thereon; and then by a Stroke of the Handle, the Piston D, is raised and the Water lying on it is discharged through the Orifice O.

The Fire Engine, or little Dutch Pump, which is often used to Water Streets or Gardens, is thus constructed.

Fig. 47. Let a Plug be fixed at C with a Valve, as in the foregoing Pump, to suffer Water to pass through it upwards, but not to return. D is a solid Piston without either Bore or Valve which is fixed to a Rod, and that to a Handle T by which it is worked. A little above the Plug C there is an Orifice O in the Side, wherein a Tube OE is inserted, in which Tube there is a fixed Plug V with a Valve that opens outwardly and suffers no Water to return. Now when the Piston D is raised it is plain that it causes a Vacuity between D and C, and the Air pressing on the Water in which the Machine stands, drives the Water through C on the Valve of which it lodges; the solid Piston D then being thrust

thrust down will drive the Water through the Orifice O, and up through the Tube or Pipe OE; but on drawing up the Piston, the Valve at V in the Tube OE immediately shuts by the Descent of the Water from E to V, and prevents it coming backwards on the Valve in the Plug C: And thus by the help of Leathern Pipes, Water may be conveyed to the Tops of the highest Houses.

That the Atmosphere is heavier at one Time than at another, we are confirmed of by the *Barometer* or Weather Glass, invented by *Torricellius*, and is thence known amongst Naturalists by the Name of the *Torricellian-tube*. It is made by filling a Glass Tube of about three Feet long with Mercury, which Tube is hermetically closed or sealed at one End, and by putting your Finger to the other End invert it in a Vessel as A or B, (*Fig. 48*) which is partly filled with Mercury without letting in any Air: Upon taking the Finger away, the Mercury in the Tube will remain suspended between 28 and 31 Inches above the Surface thereof in the Vessel.

This Mercury is kept up the Tube by the Weight or Pressure of the Atmosphere on the Mercury in the Vessel; for if the Tube and Vessel be put under a Receiver on an Air-pump, and if the Air be exhausted from the Receiver, the Mercury in the Tube will all fall down into the Vessel; and if the Air be again restored, the Mercury in the Vessel will be drove up the Tube to its former Height.

The Mercury in the Tube is never found to rise higher than 31 Inches, even when the Atmosphere

mosphere is most condensed or most weighty; nor does it ever fall lower than 28 Inches though the Atmosphere were most rarified, or in its lightest State: And hence it is that Barometers are graduated on either Side from 28 to 31 Inches, as the Barometers B and C are; and opposite to these Divisions you have Words which express the State of the Atmosphere, or what Kind of Weather will soon ensue. When the Air is most rarified, or when it is in its lightest State, it is then unable to sustain the Clouds and therefore great Rains fall; and yet we are apt to say that such Weather is very heavy: And on the contrary when the Air is most condensed, and therefore most weighty, it is most able to sustain the Clouds, and the Weather is then finest, and we are apt to say it is light Weather: For the Air when it is most rarified, is very thin, and a great Part of it glides through the Lungs, and therefore the Respiration is weak, which greatly disturbs and weakens the human Frame and renders our Spirits low and heavy, as well as those of other Animals; and again, when the Air is most dense it will not be able to ouze out of, or glide through the Lungs, and therefore it is then fittest and best for Respiration, which adds Life and Spirits to the Body, and thereby occasions us to say it is fine light Weather.

Fig. 48. The Barometer AD is a Diagonal one, whose Height from A to D is 28 Inches; let DE be 3 Inches, and thereby AE 31; if to E be drawn a perpendicular EF, and if from any Point therein as F, there be drawn the Diagonal FD:

FD: If a Tube be turned in that Direction it will more apparently shew the rise or fall of the Mercury, than either of the Barometers B or C can, and such are graduated from D to F.

The Barometer C is turned at one End, and a little above the Turn is a Cistern or Bason to receive the descending Mercury: In the Top of this Cistern there is an Orifice to let in the Air, in order that it may press upon the Mercury in the Cistern; and thereby as its Gravity increases or decreases that the Mercury may the more readily rise and fall; and these Kind of Barometers are most frequent.

Besides these Barometers here mentioned, there are the *Wheel* and *Conical* Barometers: But as they are all actuated by the foregoing Principles, it is needless to be particular about them.

In any Barometer, the Mercury in the Tube will have a convex Surface if it be rising, but if it be falling the Surface will be concave.

If the like Experiment were tried with a long Tube and Water, the Water would never be found to rise higher than 36 Feet 2 Inches, or to fall lower than 32 Feet 8 Inches; for Water, by the foregoing Table of the Specific Gravities of Bodies, is found to be 14 Times heavier than Mercury: That is to say, if the Surface of the Earth were covered 28 Inches deep with Mercury, or with 32 Feet 8 Inches depth of Water; they would press equally on it, and each Pressure would be equal to the Pressure of the Atmosphere when in its lightest State.

Hence

Hence it is that the Surface of Water in a Well must be less than 33 Feet from the End of a Pump's Piston; and yet Water may be raised by a Pump to any Height, provided the Rod of the Piston be made long enough.

The surprising Force with which the Atmosphere presses in all Directions may be further evinced, thus;

Let two Brass hollow Hemispheres each of 3 Inches Diameter, the one with a Ring on its Vertex, and the other with a Screw and Cock on its Vertex, be laid one upon the other with wet Leather between the Edges, the Screw Hemisphere being first inserted in the Plate of an Air-pump and its Cock opened; exhaust the Air that is between the Hemispheres through the screwed Neck and close the Cock: Then if the whole be unscrewed from the Plate, the two Hemispheres will be found to be so closely pressed together by the Atmosphere as to require 150 Pounds to pull them asunder when the Air is in its lightest State, and at other Times, 160, 180 or 200 Pounds will scarcely be sufficient to separate them: For these Weights will be in Proportion of the Pressure of the Atmosphere at different Times, and when it is in different States.

Hence it is that Air is found to press above $16\frac{1}{2}$ Pounds upon every Square Inch, or with a Weight of 31144 Pounds upon a midling Man, whose Surface is about 15 Square Feet; which would infallibly crush him to Pieces if the Air within him did not counterballance the external Pressure.

If a Person lays his Hand over a small open Receiver, and thence exhausts the Air, he will find so great a Weight or Pressure on the Back of his Hand as not only to give him Pain, but to endanger the breaking of his Hand; which is immediately eased by restoring the Air.

If the Brass Hemispheres which before were exhausted, and which required a great Weight to separate them, be put under a Receiver on an Air Pump, upon exhausting the Air out of the Receiver, the Hemispheres will separate and fall asunder from each other, which manifestly shews that their strong Cohesion is owing to nothing else but to the Pressure of the Atmosphere upon them.

Fig. 49. The *Siphon* or *Crane* is a bended Tube ABC, which being filled with Water, and putting the shortest Leg A into the Water, the Vessel will be emptied by passing through the Siphon, and will be discharged at the other End C, provided that End be any Thing lower than the Surface of Water in the Vessel: For the Atmosphere presses upon both Ends of the Tube and so keeps it full, but the Water in each Leg presses downwards in Proportion to their perpendicular Heights AB, AC; now seeing BC is greater than AB, the Water will yield to the greatest Pressure and therefore will be discharged at C, so long as C is lower than the Water in the Vessel.

This is the true Cause of the Siphon's running, because if a little Hole be made about the Top of the Tube while the Water is running; or if the Siphon be put under a Receiver and thence the Air be exhausted

exhausted, the Fluid in the Siphon will divide at the Top and fall down through each Leg.

Hence Water may be made to run through Pipes over any Hill, House, or Wall that is not above 33 Feet high; provided the Place you would bring it to, be lower than the Spring Head, or the Surface of the Water you would bring it from: Because 33 Feet of Water is equal to the Pressure of the Atmosphere when the Air is in its lightest State, as we have already but just shewn.

Other Fluids will rise in a Siphon to a greater or to a less Height, according to their Specific Gravities.

Fig. 50. If a Siphon a, b, c , be placed within a Vessel having one Leg passing through its Bottom: If Water be poured into this Vessel, it will not begin to run out of the Siphon till the Surface of the Water be above the Top of the Siphon: But then the Water will run down the Leg ac , which being once filled will continue to discharge the Water at c as long as there is any in the Vessel, which must be sufficiently evident from what has been already said.

In this Manner we may account for the ebbing and flowing of Springs: For if Water be imagined to run gradually into the foregoing Vessel till the Surface covers the Top of the Siphon, if then the Water runs out of the Siphon faster than the Vessel is supplied therewith, it will empty and continue to stop till the Siphon be again covered.

These intermitting Springs will be rendered more obvious, if we let ABC to represent a Hill wherein

wherein there is a Cavity C; if in this Cavity there is a Passage or Vein running in the Direction WED, then if the Rains which fall on the Hill by passing through the Pores of the Earth fill the Cavity C higher than the Top of the Vein to E, the Water or Spring at W will continue running till it has withdrawn the Water in the Cavity so low as D; and then it will stop 'till the Cavity be replenished again, and it rises above E and then it will flow again, and so on.

2. *Of the Elasticity of Air.*

By the Elasticity or springing Force of the Air, we understand it to be that Force wherewith the Particles of Air expand themselves and recede from each other, as before: And this happens when the Pressure which keeps them together is taken off.

That Air is Elastic will be evident from the following Experiments.

If Air be closely corked up in a thin Square Vial, and the Bottle be put under a Receiver on an Air Pump: Upon exhausting the Receiver the confined Air in the Vial will by its Elasticity burst the Bottle to Pieces.

Tie up a little Air in a Bladder, and put it under a Receiver; when the Air is exhausted from the Receiver, the Bladder will swell as if it were blown up.

Take a Glass of warm Ale or any other glutinous Fluid, and putting it under a Receiver, exhaust

haust the Air, and the Liquor will rise in large frothy Bubbles and run over the Glass.

For the Liquor being glutinous contains a great Number of Particles of Air, which upon removing the outward Air expand themselves; and as they cannot disengage themselves of the clammy Liquor about them, they raise it up and carry it over the Glass in the Form of Froth.

Put an empty Glass Bottle with its open Mouth down into a Glass Vessel of Water, cover both with a Receiver, and thence exhaust the Air; the Air in the Bottle will be then observed to swell and bubble through the Water.

Insert a small Glass Tube open at each End into a Bottle Part full of Water, so that the lower End of the Tube may be below the Surface of the Water; and let the Insertion be made by Means of a Screw and Collar of Leathers, in such a Manner, that no Air can pass into or out of the Neck of the Bottle: Let the Whole be then covered with a tall Receiver, and the Air being thence exhausted; the Water will rise up through the Tube in Form of a Jet, which will be higher or lower as the Receiver is more or less exhausted: for the Air in the Bottle, by its Endeavour to expand itself, presses on the Surface of the Water, and so drives it up the Tube.

The Elasticity of the Air is equal to the Pressure of the Atmosphere, because it sustains that Pressure: For the Air in the Bottle, or in any other Vessel, will expand with a Force, that is equal to that with which it is pressed; Action and Re-action being equal and contrary: And hence

hence the Elasticity of a small Quantity of Air, is equal to that of a great Quantity.

The Density of the Air is always as the Force that presses it, and therefore the Air towards the upper Part of the Atmosphere, being less pressed than that near the Earth, it will thereby become thinner; so that the farther we go up Mountains we find the Air becomes the rarer, and the Rarity is found to be such, that if Altitudes in the Air, be taken in Arithmetical Proportion the Rarities of the Air at these Altitudes will be in Geometrical Proportion. Thus,

At the Altitude of	{	7	Miles from the Surface of the Earth	{	4	Times thinner or rarer than at the Surface
		14			16	
		21			64	
		28			256	
		35			1024	
		70			1048576	

Hence we may easily by Calculation find, that a Cubic Foot of common Air at the Height of 500 Miles would be so much rarified or expanded as to fill a Sphere of equal Diameter with that of the Orbit of Saturn; and therefore the Planets may easily move through the Heavens without suffering any sensible Resistance.

Though by this Rule for finding the Rarity of the Air, there will still be Air at infinite Distances, yet at the Height of 40 or 50 Miles, it is so rare, that what is above that Distance is inconsiderable. And therefore, the Height of the Atmosphere is generally reckoned to be about 45 Miles.

Since the Density of the Air is proportionable to the Compressing Force, and this is equal to the Elastic Force; it therefore follows that in as much as the Density is increased, the Elasticity will be increased in the same Proportion.

Upon this Principle are founded artificial Fountains, which play by Means of condensed Air: They are of two Kinds, Single and Double.

Fig. 52. The single Fountain is made of Brass. and is every where shut except, that through the Middle of the Basin BB there passes down a Pipe PP, whose lower End reaches nearly to the Bottom of the Fountain, and to the upper End, there is fixed a Stop-cock, by Means of which, the Pipe may be shut or opened as Occasion requires.

Some Part of the Fountain ADC being filled with Water poured in through the Pipe, a Condenser or forcing Engine is screwed to the Top of the Pipe above the Cock, by Means whereof a great Quantity of Air is driven through the Pipe and remains condensed above the Surface of the Water in the Fountain. When therefore the Condenser is taken off, and the Cock opened, the condensed Air above the Water, pressing strongly on it, drives the Water up through the Pipe, and thereby forms a Jet.

The Force wherewith Water is thrown up, is as the Density of the included Air, above the external Air.

Fig. 53. The double Fountain consists of two single ones, as AA, and BB, fastened to a hollow Cylinder CC which plays upon the Pins DD as
upon

upon an Axis: Each Fountain has a Pipe P whose lower End reaches nearly to the Bottom of its Fountain. From the Bason of the Fountain AA there issues another Pipe TE which opens at E, in the Fountain BB, which Pipe neither communicates with the Fountain AA, nor with the hollow Cylinder CC. In like Manner there issues another Pipe in the Bason BB which passes through that Fountain and Cylinder, and opens in the Fountain AA.

The Whole Machine is then placed in an upright Posture by Means of a Carriage which supports it ; and the Pipes of the lower Fountain being stopped, water is conveyed in it through the Pipe T, which issues from the Bason of the upper Fountain ; by the running of which Water into the lower Fountain, the Air contained therein, becomes condensed ; if then, both the Pipes of the upper Fountain be stopped, and the lower Fountain be turned upon its Pins, the Water which it contains will fall to its Bottom and the lower End of the Pipe P will be immersed therein, in the Manner represented in the upper Fountain ; so that upon opening that Pipe, the Water will be driven through it, by the Elasticity of the condensed Air, and as it falls upon the Bason, it will be conveyed thence through the Pipe T, into the lower Fountain ; and when the upper is exhausted, and ceases to play ; if its Pipes be stopped, and turned downwards as before, the other may be set a going in the same Manner ; and so on as long as you please.

3. *That Heat will rarifie Air.*

Air being heated will rarifie or be made to swell and expand itself; and this Property may be fully evinced by tying up a small Quantity of Air in a Bladder, and laying it before a Fire; the Air in the Bladder will be so much rarified by the Heat, as sometimes to cause the Bladder to swell as if it were blown up tight.

Wind is a necessary Consequence of this Property of Air; for when the Air is heated by the Sun, or by any culinary Fire, it will swell and drive the adjacent Air away; and thus, by various Degrees of Heat, in different Places, there will arise various Winds.

Hence if Air be very much heated, it will ascend towards the upper Part of the Atmosphere, and the adjacent Air will rush in to supply its Place; and therefore there will be a Wind, a Stream or Current of Air from all Parts, towards the Place where the Heat is; which is the Reason, why Air rushes with great Violence, into the Door of a Glass-house, or through the Key-hole of a Door, or through any small Chink of a Room wherein is a Fire, as well as that Smoak is carried up a Chimney: Take it in general, that the Air will press towards that Part of the World which is most heated.

Upon this Account it is, that the Trade-winds at or about the Equator, constantly blow from the East towards the West; for when the Sun shines perpendicularly on any Part of the Earth, it

it will heat the Air which is over that Part greatly, and occasion it to rarifie and rise upwards; and this will occasion the adjacent Air to rush in, to fill up the Vacuity, which will consequently cause a Wind, Stream, or Current of Air from all Parts, towards the Sun: And since the Sun, with respect to the Earth, moves from East to West, the common Course of the Air will be also that Way continually pressing after the Sun; and therefore, at the Equator where the Sun shines strongly, there will be a continual Easterly Wind; but on the North Side it will incline a little to the North, and on the South Side a little to the South.

This general Course of Trade-winds, about the Equator, is changed in several Places, and upon several Accounts.

1. By the Attraction of the Moon, which on the Meridian may as reasonably be supposed to raise or swell the Air, as it does the Water in the Tides.

2. By certain Exhalations that rise out of the Earth, at certain Times, and from certain Places, by Earthquakes especially, and by Vulcanos.

3. By the fall of great Quantities of Rain, Hail, or Snow which cause a sudden Condensation or Contraction in the Air.

4. By the sudden melting of Snow on the Mountains, which causes the Condensation near them suddenly to cease.

5. By burning Sands that retain the solar Heat, to a Degree incredible to those who have not felt it, causing

causing a more than ordinary Degree of Rarefaction in the Air, which Is over them.

6. By the Opposition of high Mountains that reflect the Wind, and alter the Line of Direction.

7. By the Suns declining towards the North, or South, and thereby heating and rarefying the Air in this or that Part of the Earth All which particular Causes may chance either to conspire with, and strengthen the general one before cited, or may oppose in Part or lessen its Efforts, according to the Diversity of Time, Place, and Circumstance that may happen in the Course of Things.

To these Particulars, or such like, are owing.

1. The great irregularity, and uncertainty of Winds, in Places which are far from the Equator, as in most Parts of *Europe*.

2. Those periodical Winds, which blow half a Year one Way, and the other half another Way, as in the *Indian Sea*.

3. Those Winds, which on the Coasts of *Guinea*, and on the Western Coasts of *America* blow always from the West to the East.

4. Sea Breezes, which in hot Countries blow generally from Sea to Land in the Day Time; and the Land Breeze, which blows in the Night: And in short all those Storms, Hurricanes, Whirlwinds, and Irregularities which happen in different Times and Places, must proceed from some such Causes as those before mentioned.

Particular Descriptions of the Motions of the Air in various Parts of the World might be easily given, but as this would be a tedious Task, we shall

shall proceed to explain the Nature of
Sounds.

That Sounds depend on the tremulous Motions of the Air, will be manifest by placing a Bell under a Receiver, in such a Manner as that it may be rung at Pleasure; upon drawing the Air out of the Receiver, the Sound of the Bell will be less and less audible the more the Air is exhausted, so as at last almost to die away and scarcely to be heard; and again upon readmitting the Air, the Sound will revive and will increase the more as the Air is let in.

When the Parts of a Bell, Drum, Musical String, or any other Elastic Body, are set in Motion by a Stroke, they vibrate, or move forward and backward alternately through very small Spaces; in going forward they compress the Air, and in returning backward the compressed Air expands itself; so that the Parts of the Air, which are contiguous to the sonorous or trembling Body, go and return in the same Manner, with the Parts of the Body, and these again agitate those Parts of the Air which are beyond them, and so on 'till at last the Motion ceases: So that Sounds are propagated every Way, as it were from the Center to the Superficies of a Sphere.

The Propagation of Sounds may very well be compared with Circles made in the Water, by throwing a Stone into it. And as those which are made in a running Stream, extend themselves further towards the lower than towards the upper Part of the River, because the whole Water in

which they are formed carries them that way: So likewise we may conceive, that if the Wind carries the Air towards one certain Place, the trembling Motion in which Sound consists, will sooner go in this way than the contrary. Thus we find by Experience, that the Sound of a Canon, and in general all other Sounds are heard sooner with the Wind than against it. And it may happen, that Air may be moved so quick, that its Parts may fly from us as fast as the Sound goes, and so it may not be heard at all.

Because the trembling Motion of the Air, in which Sounds consist, is communicated gradually, so as to affect those Parts which are near the sounding Body, sooner than those that are further off, the Sound must necessarily take up some Time in going along, and thus we find by Experience, that if a Canon be discharged at two or three Miles Distance, that we see the Flash some Time before we hear the Noise.

Hence the Velocity of Sound is found to be 1142 Feet in one second of Time; and thus the Distance of any Ship that fires a Gun at Sea, may be known by means of a Watch that measures Seconds, by observing the Time between the Flash and the Report.

The further the sounding Body is off, the less will be the Noise, because the tremulous Motion of the Air spreads wider successively, and thereby becomes weaker 'till at length it dies away.

The Sounds of Musical Strings, consist in the Agitation they are put in, by the Bow being made rough with Rosin; for if the Bow be rubbed
with

with Tallow or Oil, the Strings will have no Sound, because they slip under, and are not shaken by it.

The Sounds of drinking Glasses, as made by rubbing the Finger about the Rims, are of the same Nature with the Strings of a Violin; for the Finger here supplies the Place of a Bow.

The Sound of a Bell is occasioned by the Stroke of the Clapper against it, which alters its Figure a little from a Circle to an Oval: And because it is made of a Metal stiff, but elastic or springy, that Part which is most distant from the Center, returns towards it something nearer than at first; so that the Places which were the Extremities of the longest, will become those of the shortest Diameter; and thus the Figure of the Bell is changed all the Time it is ringing. This will be more manifest to any Person who lays his Hand upon a large Bell, just when the Clapper strikes, for he will be affected with a surprizing Numness; and the Hand being laid upon a small Bell will either damp, or quite stop its Sound.

The Sound raised by striking a piece of Wood, or in general any hard sounding Body, consists in its tremulous Motion, which is owing to its Elasticity or springing Force.

Hence all Bodies that are void of Elasticity, have a low or imperfect Sound.

Since Sound is propagated every Way, from the Center to the Surface of a Sphere, it is plain that two Persons who are not in the same concentric Circle or Sphere cannot hear the Sound at the same Instant of Time. And if the Motion

of Air, which might be communicated to a great Distance, meets some hard Body which it cannot shake, it may cause the Motion to reflect or return backward, and this redoubled Sound is called an *Echo*.

If Sound meets several Bodies at different Distances, which are capable of reflecting it back again, and if that which returns from the most distant Place, strikes upon the Ear, after the Impression of the former is quite gone off, it must in its turn produce a new Sensation of Sound. Hence it is evident we may meet with *Echos* which will repeat the same Word several Times.

The more a Musical String is *strained*, the *sharper* is the Sound, for its Vibrations will become the quicker; and the *looser* the Strings are, the Vibrations will be *slower*; and therefore the Sound will be more *flat*: And this is the Reason of *Flats* and *Sharps* in Music.

When two sounding Bodies strike the Air at the same Time, they impress such a Motion upon it, as is compounded of the two Motions, if they acted upon it separately; and consequently the Air puts the *Organ* of hearing, into such a tremulous Sort of Motion, as gives a Sensation of distinguishing the two Sounds separately.

If two Strings, or any other sounding Bodies, do so exactly agree in their *Vibrations* of *Pulses*, as to strike the Air at one and the same Time, or if they strike together every second or third Stroke; or if one performs 5 whilst the other performs 6 Vibrations; then the Ear will be uniformly struck upon, and in such a Measure,
that

that it will perceive the Distance, and be pleased with the Cadence; and this is the Reason why Musicians call these Pulses *Concords*; as an *Unison* and *Octave*, a *Fifth* and a *Third* are.

On the contrary, if Vibrations so far disagree as not to strike together, or meet each other, we must perceive an inequality, and something disagreeable and harsh in the Sounds; and these Musicians call *Discords*.

Some may perhaps think that the longest and shortest Vibrations of a Musical String, are not performed in the same Time; but upon due examination they will find them to be exactly equal.

If two Strings of the same or of different *Lutes* be *Unisons*, that is, if the Number of Vibrations of the one be equal to those of the other, in the same Time, we cannot move one but the other will sound also, or at least it will tremble; whereas it will not tremble at all, if we move any other String near it which is a *Discord*. For the Strings which are *Concords* being capable of the same Vibrations, very conveniently communicate them to each other, and there can be no Agreement in them, if the Strings are not *Unisons*, because the Air which is put in Motion by the one, does not find the other disposed to receive its Motion; since every Stroke except the first being out of Time they conspire to destroy each other's Motion.

This Disposition that a Body has to move, when the Air is shaken by another Body, is to be found in other Things as well as in the
Strings

Strings of a Lute, or other Musical Instrument : This has been experienced by Gentlemen in the Army, when they have observed the Glass Windows to tremble very sensibly upon beating of a certain Drum, and at the same Time would not tremble at all upon beating of others which are much louder.

So likewise if two Glasses, by putting in a proper Quantity of Water, be made *Unisons*; the pressing of our Finger hard upon the Edge of either of them, and moving it round, will make the Water in the other curl, and dance about.

Mr. *Boyle* tells us that upon discharging of Canons, a sick Man who had his left Hand cut off, thought himself almost shattered and torn to Pieces; of another that upon scraping a piece of Iron with a Knife, he could not hold his Water; and of a third, that upon tearing thick Paper his Gums would bleed.

To these sort of Motions may be ascribed the Cause of certain *Shiverings*, which we sometimes feel all over our Body, and which reaches even to the Heart, upon hearing the sound of a Trumpet, a Concert of Music, &c. For it may be that the Blood is disposed to yield easily to the trembling of the Air.

And because the Membrane or *Drum* of the Ear, which is something like Parchment, being agitated by the external Air, causes different Motions on the Capilliments of the Nerves of the Ear; therefore it will be more or less shaken according as it is more or less stretched; so that

Attention

Attention consists in nothing else but in a due stretching or loosening of this Membrane, and by keeping it in that Position where it will best receive the Impression and Motion which Sound gives to the external Air.

Of the Diving Bell.

The Diving Bell is a large Vessel of Wood or Copper, with Weights about the Bottom in Order to make it sink, when full of Air, with the Mouth of the Bell downwards: The Diver sitting under his Bell is let down with the included Air, to the Depth desired.

The Management of this Machine depends upon the Knowledge of the following Principles.

1. That a Body being immersed in a homogeneous or a like Fluid, is always pressed with a Force proportional to its Distance from the Surface.

2. That the Density of Air is always as the Force that presses it, that is with a double Pressure, it will be pressed into half, or with a triple Pressure into one third of the Space it before possessed.

3. That Air is vitiated by passing through the Lungs of Animals.

Doctor Halley's Description of his Diving Bell.

“The Bell I made use of was of Wood, containing about sixty Cubic Feet in its Concavity, and was in the Form of a *Truncate Cone*, whose
Diameter

Diameter at the Top was three Feet, and at bottom five. This I coated with Lead so heavy that it would sink empty, and I distributed the Weight so about its Bottom, that it would go down in a perpendicular Situation and no other. In the Top I fixed a strong, but clear Glass, as a Window to let in the Light from above; and likewise a Cock to let out the hot Air that had been breathed; and below, about a Yard under the Bell, I placed a *Stage* which hung by three Ropes, each of which was charged with about one Hundred Weight, to keep it steady. This Machine I suspended from the Mast of a Ship by a *Sprit*, which was sufficiently secured by *Stays* to the Mast Head, and was directed by *Braces* to carry it over Board, clear of the the Ship's Side, and to bring it again within Board, as Occasion required.

To supply Air to this Bell when under Water I caused a couple of Barrels of about thirty-six Gallons each, to be cased with Lead, so as to sink empty; each having a Bung Hole in its lowest Part to let in the Water, as the Air in them condensed on their Descent; and to let it out again when they were drawn up full from below: And to a Hole in the uppermost Part of these Barrels, I fixed a leathern Trunk or *Hose*, well liquored with Bees.wax and Oil, and long enough to fall below the Bung-hole, being kept down by a Weight appended, so that the Air in the upper Part of the Barrel, could not escape unless the lower Ends of the *Hose* were first lifted up.

The Air Barrels being thus prepared, I fitted them with Tackle proper to make them rise and fall alternately, after the Manner of two Buckets in a Well. Which was done with so much Ease, that two Men with less than half their Strength could perform all the Labour required; and in their Descent they were directed by Lines fastened to the under Edge of the Bell, the which passed through Rings placed on both Sides of the Leathern *Hose* in each Barrel; so that sliding down by those Lines, they came readily to the Hand of a Man who stood on the Stage, on purpose to receive them, and to take up the Ends of the *Hose* into the Bell. Through these *Hose*, as soon as their Ends came above the Surface of the Water in the Barrels, all the Air that was included in the upper Parts of them, was blown with great Force into the Bell, while the Water entered at the Bung-holes below and filled them; and as soon as the Air of the one Barrel, had been thus received, upon a Signal given, that was drawn up, and at the same Time the other descended; and by an alternate Succession, furnished Air so quick and in so great plenty, that I myself have been one of five, who have been together at the Bottom, in nine or ten Fathoms Water, for above an Hour and a half at a Time, without any sort of ill Consequence; and I might have continued there as long as I pleased, for any Thing that appeared to the contrary. Besides, the whole Cavity of the Bell was kept entirely free from Water, so that I sat on the Bench, which was diametrically placed near the Bottom, wholly

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dressed

dressed with all my Cloaths on ; I only observed that it is necessary to be let down gradually at first, at about twelve Feet at a Time, and then stop and drive out the Water that entered, by receiving three or four Barrels of fresh Air, before I descended farther. But being arrived at the Depth designed, I then let out as much of the hot Air that had been breathed, as each Barrel would replenish with cool, by means of the Cock at the Top of the Bell ; through whose Aperture, though very small, the Air would rush with so much Violence, as to make the Surface of the Sea boil ; and cover it with a white Foam, notwithstanding the great Weight of Water over us.

Thus I found I could do any Thing that was required to be done just under us ; and that by taking off the Stage, I could for a Space as wide as the Circuit of the Bell, lay the Bottom of the Sea so far dry, as not to be over Shoes thereon. And by the Glass-window, so much Light was transmitted, that when the Sea was clear, and especially when the Sun shone, I could see perfectly well to write or read, much more to fasten and lay hold of any Thing under us that was to be taken up. And by the return of the Air Barrels, I often sent up Orders, written with an Iron Pen on small Plates of Lead, directing how to move us from Place to Place as Occasion required. At other Times when the Water was troubled and thick, it would be as dark as Night below ; but in such a Case I have been able to keep a Candle burning in the Bell

as long as I pleased, notwithstanding the great Expence of Air requisite to maintain Flame.

This I take to be an Invention applicable to various Uses; such as *Fishing* for *Pearl*, *Diving* for *Coral*, *Spunges* and the like, in far greater Depths than has hitherto been thought possible: Also for fitting and plaining of the Foundation of Moles, Bridges, &c. upon rocky Bottoms and for the cleaning and scrubbing of Ships Bottoms when foul, in calm Weather at Sea. But as I have no Experience of these Matters, I leave them to those that please to try. I shall only intimate, that by an additional * Contrivance, I have found it not impracticable for a Diver to go out of our Engine to a good Distance from it, the Air being conveyed to him with a continued Stream, by small flexible Pipes; which Pipes may serve as a Clew to direct him back again when he would return to the Bell."

CHAP.

* The Contrivance here mentioned, was a Vessel made in the Shape of a Bell, so big as to cover a Man's Head and Shoulders; this was put over a Divers Head and with it he walk'd out of the Bell upon the Bottom of the Sea up and down, and had the Air conveyed to him by flexible Tubes.

C H A P. VI.

Of Optics, or the Properties of Light.

LIGHT is a most subtile Fluid whose particles are extreamly small; and are thrown off from Luminous Bodies by the vibrating Motions of their Parts with a surprizing great Velocity; for it is found by means of the *Eclipses* of the *Satellites* of JUPITER that they pass from the Sun to the Earth in about seven Minutes; for these Eclipses when the Earth is between the Sun and JUPITER, are found to happen about seven Minutes sooner than they ought to do by Astronomical Tables; and when the Earth is beyond the Sun with respect to JUPITER, they happen about seven Minutes later than they ought to do; so that in the latter Situation of the Earth, they are found to happen about fourteen Minutes later than in the former; that is light will pass through the Diameter of the Earths Orbit in fourteen Minutes, or from the Sun to the Earth, which is Eighty-one Millions of Miles in seven Minutes.

Droptics or the Nature of the Refraction of Light.

That the Motion of Light is rectilineal is evident from the Shadows which opaque Bodies cast when placed in the Light of the Sun, or of
any

any other luminous Body; and yet the Beams or Rays of Light, in passing out of one transparent Body or *Medium*, as Air, Water, Glass, Diamond, a Vacuum, &c. into another of a different Density, are bent or turned out of their Way, or they are made to change the Direction of their Motion; and this bending or change of Direction is called *Refraction*; and it is found, that Rays which pass from a rarer into a denser *Medium*, bend towards a perpendicular Line, let fallen from the Point of Incidence on the refracting Surface; and on the contrary, when they pass out of a Denser into the rarer *Medium*, they decline or bend from that Perpendicular.

Fig. 54. Thus let the Vessel ABCD which we are first to suppose to be empty, be placed where the Sun shines obliquely, and let the Point B where the shadow of the Brim D falls on the Bottom of the Vessel, be observed; then let the Vessel be filled to any Height as EF with Water, and let the Point of Incidence L where the Shadow of the Brim D, or the Ray IL, will fall on the Surface of the Water, be also observed; and suppose the Perpendicular GLH to be drawn through the Point of Incidence L; then it will be found that the Shadow of the Brim will no longer be seen in the Point B at the Bottom of the Vessel, but at some other Point, as at K which is nearer to the said Perpendicular; for by Degrees, as the Water is poured in, the Shadow at B will be found to creep nearer and nearer to the Perpendicular, the more you fill the Vessel, that is, it will be the more refracted towards the Perpen-

Perpendicular, the more the Vessel is filled. And on the contrary, if we suppose K L M to be a Ray of Light passing from Water into Air, instead of its Motion being found in M L the Direction of the Line L K, it will be found to recede more from the Perpendicular, or to L D I.

If a Stick be laid over a Vessel when the Sun is in the Zenith or directly over Head, the Shadow will fall upon the same Part of the Bottom of the Vessel whether it be full or empty; so that Perpendicular Rays suffer no Refraction.

The bending of Rays or Refraction to or from the Perpendicular, seems owing to the Superiority of Attraction, that the denser has to the rarer Medium; which is also more or less, as the Rays fall more or less obliquely on the refracting Surface, which divides the Mediums.

Put the End of a strait Stick obliquely into a Vessel of Water, and look upon it obliquely, it will appear to be bended at the Surface of the Water, in the same Manner as the Rays of Light are bent, but in a contrary Direction.

If you put a Shilling at the Bottom of a Bason or Cup, and withdraw yourself from it by Degrees, so as to loose the Sight of the Shilling, then if the Vessel be but partly filled with Water, you will see the Shilling very plainly.

Hence it is that we always see the Sun before it rises, and after it sets, because the Atmosphere about the Earths Surface is more dense at the rising

rising or setting of the Sun, than at any other Time of the Day.

What has been said of Water may be applied to any other transparent Body, only the Refraction of some is greater than in others.

The Angle ILG (see the foregoing Figure) contained between the Ray IL and the Perpendicular LG is called the *Angle of Incidence*, and the Angle KLH contained between the same Perpendicular, and the same Ray after Refraction, is called the *Angle of Refraction*.

The Sine of the Angle of Incidence, is to the Sine of the Angle of Refraction, always in a given Ratio. Thus, When a Ray of Light passes out of Air into Glass, the Ratio is as 3 to 2, out of Air into Water as 4 to 3, out of Air into Diamond as 5 to 2.

Hence we may easily see, how Rays will pass through all sorts of Glasses.

Of Glasses.

Glass may be ground into these six different Shapes.

1. *A plane Glass*, or one that is ground quite plane or flat on each Side, and whose Parts are every where equally thick.

2. *A Plano-convex*, or one that is plane or flat on one Side, and Convex or round on the other.

3. *A Double-convex*, or one that is Convex on each Side.

4. *A Plano-concave*, or one that is concave or hollow on the one Side, but plain on the other.

5. *A Double-concave*, or one that is concave on each Side.

6. *A Miniscus*, or one that is ground concave on one Side, and convex on the other. And of these in Order.

1. *Fig. 55.* If a Ray of Light, passes through a plane Glass, it will go in and pass out in the same Direction, though not precisely in the same Right-line: Thus, if a Ray of Light RD fall obliquely on the Surface of the Glass AD, it will be refracted in the Direction CD, from what has been just said; but when it comes out of the Glass at C into the Air, it will be refracted in a contrary Way; so that EC will be parrallel to RD.

2. *Fig. 56.* If parallel Rays of Light pass through a Convex Glass, they will be collected and converge in a Point behind it: Thus, the Ray RD which falls perpendicularly in the Middle of the Glass, will go through it without suffering any Refraction as hath been already shewn; but the Ray ST which passes through the Side of the Glass, falls obliquely upon the Surface, and will therefore be refracted, and in coming through the Glass will meet each other at F and compose a *Pencil of Rays*; and the nearer the Verge of the Glass the Rays fall, the more oblique they will be, and therefore will be more refracted; and hence it is that the Point F which is called the principal *Focus* will be nearer to, or further from the Glass, as the

the Glass is more or less convex, or as the Rays are more or less refracted.

Hence it also is, that a convex Glass will set fire to Things, by the Suns Rays passing through it.

This *Focal Distance*, or Distance of the Glass from the Focus, is equal to twice the Radius of the convex Surface, in *Plano-convex* Glasses; and in a Glass which is equally convex on each Side it is once the Radius of either Surface; but if a Glass be more convex on one Side than on the other, divide twice the Product of the Radii by their Sum, and the Quotient will be the Focal Distance Sought.

Fig. 57. If a Ray of Light passes obliquely through a convex Glass, it will go forward in the same Manner as if it had passed through a plane Glass; that is, it will come out of the Glass in the same Direction in which it entered: For the Ray *RD* will be refracted at the points *D* and *E* in the same Manner, as if it had passed through the plane Surfaces *ab*, *cd*, which are parallel to each other, as is easy to conceive; but if Rays as *RB*, *RP* pass through the Side of the Glass, they will be refracted, and so will converge and meet each other in *F*; and on the contrary, the Rays *FB*, *FP*, which flow from the Point *F*, will be also refracted and will meet each other in the Point *R*.

The Rays that flow through a double convex Glass, or a double *Convex-Lens* from any Object, will paint an inverted Picture of that Object, upon any white Body, which is placed at the *Focus* of the *Lens*.

Fig. 58. Let *LS* be the double *Convex-lens*, and let *AH* be the Object to be painted in an inverted Position be placed before it, the Rays which flow from the Point *A* will be refracted by the *Lens* and unite in the Point *a*; in like Manner those Rays which flow from the several Points *B, C, D, E, F, G, H* of the Object *AH* will unite in the Points *b, c, d, e, f, g, h*; therefore if the *Lens* be inserted into a round Hole cut in a Window Shutter, and if the Room be darkened, and the Object be placed before the *Lens*, and if a Sheet of white Paper, or any other white Body, be placed at a proper Distance behind the Glass, there will be found a true and perfect Picture of the Object in all its Colours; but in an inverted Position.

In the like Manner, Houses, Persons, or Carriages passing by may be seen in an inverted Position; and in Order to see them the more distinctly it is necessary that the Sun should shine on them at the Time of making the Experiment.

† The Distance of the Picture from the Glass may be found if the Distance of the principal Focus be found as before, and the Distance of the Object from the *Lens* be known: thus, multiply the Distance of the principal Focus by the Distance of the Object, and divide the Product by their Difference, and the Quotient will be the Distance of the Picture from the Glass.

If the Object be brought nearer to the *Lens* the Picture will be removed to a greater Distance, for the Rays which flow from any single Point, will diverge or spread more as they fall upon the Glass,

Glass, and therefore they cannot so soon converge or meet together behind it. If the Distance of the Object from the Glass be equal to the Distance of the principal Focus of that Glass, the Rays which flow from any one single Point of the Object will be so refracted by passing through the Glass, that they will go out of it parallel to each other, and therefore there can be no Picture behind the Glass. ✱

The Picture that is made by a *Convex-lens* or Glass, will be as much bigger or less than the Objects, as its Distance from the Glass is more or less, than the Distance of that of the Object from the Glass; thus as DI is to Id, so is AH to ah. (*See the foregoing Figure.*)

The Appearances of a *Camera-obscura* owe their Formation to a double *Convex-lens* being fixed to the Extremity of a Tube, which issues Horizontally from one Side of a small square Box, wherein is a looking Glass, a Speculum or a plane Mirror, put slantways from Corner to Corner, so as to make half a right Angle with the Bottom of the Box; the Top of the Box is covered with a flat Glass ground only on one Side, which receives the Pictures of Objects, thus,

Fig. 59. Let AB be an Object, placed before the *Lens* CD which is fixed to the End of the Tube to the Box; GH the looking Glass which makes with the Bottom of the Box HF half a right Angle; GM the rough Glass Plate that receives the Picture of the Object. The Rays which flow from the uppermost Part of the Object A, after passing the *Lens* would converge in F, were

R 2

they

they not intercepted by the looking Glafs GH which reflects them upwards, where they will meet in some Point K, which is as far above the *Speculum* as the Point F is behind it. In like Manner the Rays which flow from the lowest Part of the Object B would converge in E, were they not reflected by the *Speculum* to meet in the Point I which is as much above it, as the Point E is behind it; and since the Rays from the extream Points A and B, of the Object AB, convene at K and I, so all the intermediate Points of the Object AB, will convene between K and I, and the Object AB will be painted on the Horizontal rough Glafs Plate GM, between the Points K and I.

The *Magic Lantern* is a Lantern out of which issues an Horizontal Tube capable of being made longer or shorter as may be found necessary, by means of one Part moving or sliding within the other; to the Extremity of this Tube is fitted a double *Convex-Lens*, and in the other End next the Lantern is inserted a *plano Convex-glass* with the flat Side next the Lantern; within the Lantern opposite to this Glafs is fixed a Light, which passes through that Glafs, and thereby is thrown very strongly upon little frightful Images painted in dilute Colours on Pieces of thin Glafs, five or six of which being fixed in a Slider, are moved to and fro across a square Arm, which is placed between the two Glasses: These Figures are thrust through this Arm in an inverted Position, and by Means of the *Lens* at the Extremity of the Tube, are painted in an erect Position, on a
white

white Cloath placed at a proper Distance; which Distance may readily be found by drawing out or putting in the moveable Tube, or by moving the Lantern or the Cloath to a greater or to a less Distance from each other till the Images become distinct.

Having fully shewn that convex Glasses cause the Rays to converge and to meet in one Point, it remains now to shew that Rays which pass through a concave *Lens* will diverge more after they have passed through such Glasses, than they did before; thus, *Fig. 60* two Rays AB and AC which diverge from the Point A through the *Lens* BC, will not continue to proceed in the Direction of those Lines towards D and E, but will diverge more or open wider towards F and G. Again, if FB and GC be two Rays converging towards H, after they have passed the Glass, they will converge much slower or much further towards A. For if a Candle be placed before a *Convex-lens*, and its Image be received on white Paper as before; then if a *Concave-lens* be interposed between the convex one and the Image, the Image will thereby be projected to a greater Distance and become more enlarged than before, but it will be less distinct.

Of Vision.

Having shewn how the Rays of Light pass through *Convex* and *Concave-lens*'s, we are now to shew how they will be affected by passing through the Humours of the Eye.

If a small Portion be cut off a Globe, and if in Lieu thereof, a Portion of a smaller Globe, but of the same Base with the Segment, be substituted, they conjunctly will exhibit the true Form of the Eye, since the Eye is more convex before than in any other Part.

Fig. 61. The Eye consists of several Membranes or Coats which lie within each other, of which the outermost is called the *Tunica Adnata*, or *Conjunctiva*; it has its rise from that Membrane which invests the Skull, and it covers the whole Ball of the Eye, except the foremost transparent Part, which projects without the Eye-Lids, and what is commonly called the *White of the Eye*, but by Anatomists the *Cornea*.

Besides this Membrane which is not reckoned with the Coats of the Eye, there are three which are properly called Coats; the first or that under the *Conjunctiva* is called the *Sclerotica* as SS, which is very tough, and is derived from the *Dura Mater*, which encompasses the Eye with the *Optic Nerve*, the fore Part of it becomes transparent like polished Horn, and is thence called the *Cornea* as ABC.

The second Membrane is called the *Tunica Coroides*, as CC, it is derived from the *Pia Mater*, and is also transmitted from the Brain through the *Optic Nerve*, but it is much thinner than the former; the fore Part of this Coat is called the *Uvea* or the *Iris*, and is that Circle that encompasses the *Pupil*, or what is commonly called the Sight of the Eye. The Iris consists of several concentric muscular Fibres, which are joined across at right Angles by other strait Fibres like

Radii

Radii, so that by the Contraction of the former, the *Pupil* is lessened; but it is enlarged by the Contraction of the latter.

The third Coat is called the *Retina*, as *RR*; and it is the *Optic Nerve* that spreads itself over the Bottom of the Eye, opposite to the *Pupil*. These Coats contain a *Capsula* or Bag, wherein are the three Humors of the Eye.

The first we shall notice is the *crystalline Humor* which is convex on both Sides, but something flatter before than behind as *CH*; it is supported by small muscular Fibres, as *Af* and *Cf*, called *Ciliary Ligaments*, which are inserted into this Humor as well as into the *Choroides*, and being closely united form a Membrane which separates two other Humors of the Eye; the foremost of which is called the *Aqueous Humor*, or what is contained between *ABCff*, because it is of the Consistence of Water and like thereto, being very limpid and transparent; and in the hindmost is lodged the *Vitreous Humor* *VV*, which has that Name, because it resembles melted Glass. And behind all these is the *Optic Nerve* *O*.

From what has been said of *Convex-lens*'s, and of the Eye, it will plainly follow, that as any Object may be collected on the other Side of a *Convex-lens*; so the Humors of the Eye in general, but more particularly the *Crystalline Humor*, being the same as a *Convex-lens*, the Rays which flow from the Object will meet upon the Bottom of the Eye, and there make an inverted Picture on the *Retina*; just as if the same Object were pictured upon a white Cloath behind a *Convex-lens*.

For

For if you take a fresh Bullock's Eye, and cut away from the back Part, the Coats or Skin which cover the *Vitreous* Humor: then by placing a white Paper upon that Part, and by holding the Eye towards a lighted Candle, or any bright Object, so that the Rays which flow from it, may pass through the *Pupil*, you will then find the inverted Object upon the Paper, *Fig. 62.* for the Rays which flow from the Point A unite on the *Retina* at a, and those which flow from the Point B unite in b, and all the intermediate Points in the Object AB, are united on the intermediate Points on the *Retina*, and so produce an inverted Image of the Object thereon. But this union of Rays depend upon distinct Vision; for should they be united before they reach the *Retina*, or beyond it, the Rays issuing from one Point in either Case, will not unite but spread and take up some Space on the *Retina*, and therefore those which flow from contiguous Points of the Object will be so mixed and blended, that the Representation of the Object will be very confused.

Hence it is necessary that the Eye must be contracted or dilated in Order to see Objects at different Distances distinctly; in Order that the *Cornea* may become more or less Convex, so as to increase or lessen the refractive Force; which is done by Means of six Muscles which are inserted in the *Sclerotica*; and this most Men are able to do.

But there are some defective in this Point, who are unable to see any Thing distinctly, but when placed very near; and this is the Case of their Eyes who are called *Myopes*, purblind and short sighted;

sighted; in such the *Cornea* is too convex, and therefore the Rays converge before they reach the *Retina*: Such Persons Eyes are most lasting; because as the Eyes of all Persons flatten by Age, for want of a due Supply of Humors, the Rays will converge more and more towards the *Retina*, and perhaps at length meet it when they become old, and thereby they will enjoy distinct Vision.

Concave Glasses are found very useful to purblind People, for they cause the Rays to diverge so much, notwithstanding the great convexity of the *Cornea*, that they will not meet till they arrive at the *Retina*, and thus they render the Object distinct.

Such Persons as have seen distinctly, and whose Sight begins to fail them, find that Things near them cannot be so well seen as others, that are more remote; for in old Men the *Cornea* becomes flat for want of a due supply of Humors, and therefore the Rays will converge beyond the *Retina*, and consequently on it, they will diverge and scatter, and thereby render near Objects indistinct.

The proper Remedy for this Defect is a *Convex-lens* which will lessen the Divergency and cause the Rays to meet on the *Retina*.

If there be two old Persons such, that one of them can see at smaller Distances than the other; in Order to make them both see at any lesser given Distance; the Eye which can see at a smaller Distance must be furnished with a Glass of a greater *Radius* than the other. And herein consists the Secret of younger and older Spectacles, those being deemed youngest that are ground to the greatest

Radius. Or thus, the flatter and older the Eye is, the more Convex must be the Glasses to see through.

Catoptrics or the Nature of the Reflection of Light and of Colours.

If a Ray of Light falls upon an opaque dark Body, Part of it will be reflected, and Part will enter the Body and be lost in its Pores; but if a Ray falls upon a transparent Body, Part of it will be reflected, and Part will enter the Body and be refracted, as before set forth; and this was the general Opinion of all Writers upon *Optics*, before Sir ISAAC NEWTON who has shewn in the 8th *Proposition* of the 2d *Book of his Optics*, that the Particles of Light are turned backwards before they touch the reflecting Body, by some Power which is equally diffused all over its Surface; but whether the Particles of Light be reflected by striking on the Body, or whether they be repelled or reflected before they touch the Body, this Law will obtain; that the Angle of Incidence or that contained between the incident Ray and a Line drawn perpendicular to the reflecting Surface at the Point of Incidence, is equal to the Angle of Reflection, or to that which is contained between the same perpendicular and the reflected Ray.

Fig. 63. Thus, if AB be a reflecting Surface, and if CD be a Ray of Light fallen thereon, it will be reflected in the Line DE, so that the Angle of Incidence CDF will be equal to the Angle of Reflection EDF; wherefore if it falls perpendicu-
larly

larly, it will be reflected back into the perpendicular DF.

By Reflection from a plane *Speculum* or *Mirror* of very smooth Metal, or even from a well ground looking Glass, an Object seems to appear as far behind it as it is before it: *Fig. 64.* For the Rays which flow from the Point A of the Object AB will fall upon the *Mirror* MR in P, and will thence be reflected to the Eye at E by the foregoing Law, and therefore will enter the Eye as if they flowed from *a*: In like Manner the Rays which flow from B, will meet the *Mirror* at F and will be thence reflected to the Eye at E, and of Course appear to the Eye as if they had issued from *b*; therefore the Object AB will appear to be at *ab*.

In like Manner it may be easy to conceive from *Figures, 65, 66.* why the Object appears bigger in the *Concave Mirror* represented in the first Figure; and why in the second Figure it appears to be less than it really is, in a *Convex Mirror*.

Fig. 67. If parallel Rays, as *ab, ab, ab, &c.* fall upon a concave Mirror MR they will be reflected into a Point F, called the *principal Focus*.

This is the Reason why the Suns Rays reflected from a *concave Mirror*, burn with incredible Force in that Point.

If an Object be placed before a *concave Mirror*, at a Distance that is greater than the principal Focus, the Rays which flow from it being reflected by the *Mirror*, will make an inverted Picture of the Object, upon any white Body placed to receive

them; provided it be set beyond that Point where the refracted Rays will cross one another.

Fig. 68. Let MR be a *concave Mirror*, and AB the Object; the Rays issuing from A which fall on the *Mirror* at P, will be reflected along the Line PD making the Angle of Reflection equal to the Angle of Incidence; and the Rays issuing from the Point B which fall on the *Mirror* at C, will be reflected along the Line CE; if then a Sheet of white Paper as ST be placed perpendicularly any where beyond the Point G, where the reflected Rays concur or cross each other; you will have on it the Picture ba of the Object AB in an inverted Position.

If the Eye be placed beyond the Sheet as at E in the Continuation of the reflected Rays Cb, Pa, it will receive them as if they flowed from a real Object at ba; and hence we see the Reason of the odd Phænomenon exhibited by a *concave Mirror*, of a Body seeming to be suspended in the Air between the Eye and the Mirror.

The nearer the Object is to the principal Focus, it is easy to see from the foregoing Figure and what has been said, that the greater Distance the Picture must be from the *Mirror* in order to make it of an equal Size, and the contrary; for the Rays will diverge more as they fall upon the *Mirror*. What has been said of Pictures made by *Convex Glasses* will hold good of those which are made of *Concave Mirrors*.

To find the Distance of the Picture from the *Mirror*, multiply the Distance of the Object from the *Mirror* into the Radius of its Concavity,
and

and divide that Product by the Difference between twice the Distance of the Object from the *Mirror*, and the said Radius, the Quotient will be the Distance required.

It has been already shewn how the Rays of Light are refracted, by passing through different Mediums; we come now to shew how some Rays of Light are more refracted than others,; and that accordingly as they are differently refracted, they excite in our Minds, Ideas of different *Colours*.

Fig. 69. Let the Sun shine into a dark Chamber through a small Hole at H, cut in a Window Shutter, so long and broad as to fit a Triangular *Glass Prism* as A: Place then the Prism so before the Hole, that the Rays of Light HA which pass through the Hole, may fall obliquely on one of its Sides, and they will suffer different Refractions by passing through Parts of the Prism that are of different Densities; so that instead of their going out in one Direction they will pass in different Directions, represented by the Lines AB, AC, AD, &c. and in falling either on the opposite Side of the Room or upon a white Paper, will paint thereon a Series of most beautiful and lively Colours, in this Order: Those that are least refracted by the Prism, and therefore go in the Direction of the Line AB, will be of a very bright and intense *Red*, the next going in the Direction AC will be of an *Orange* Colour, then will follow *Yellow*, *Green*, *Blue*, *Purple* and *Violet*.

There are different Degrees in all these Colours: Thus, the Red degenerates by Degrees into an Orange,

Orange, the Orange into a Yellow, the Yellow into a Green, &c.

There is not an equal Quantity of Rays belonging to each of these Colours; for if the oblong Column or Series of Colours BK be divided into 360 equal Parts; Sir ISAAC NEWTON has shewn, that the Red took up 45 of them, the Orange 27, the Yellow 48, the Green 60, the Blue 60, the Purple 40, and the Violet 80.

If all these Colours be blended together, they will make a white; thus,

Fig. 70. Having divided the Rays of the Sun by a Prism as before mentioned, receive them upon a *convex Lens* as LS, which will refract them in such a Manner, that they will cross each other at F, and if a white Paper as DE be placed there to receive them, we shall find they will excite the Idea of a strong White; but if the Paper be placed further from the Glass as at FG, the different Colours will appear again in a contrary Order: And if any one of the Colours be interrupted by an opaque Plane as BC before it meets at F, the white will be inclining to a Violet or a Red, according as the Red or Violet Rays are stopped.

When a Ray of Light is once separated from the rest, it cannot be divided into any other Colours, though it be never so often reflected or refracted.

As White is a Composition of all Colours, so is black a Privation of them all, and is therefore properly called no Colour.

Any

Any one of these Colours except Red, may be made by mixing together the two adjoining prismatic Colours: Thus, Orange and Green being mixed, will make a Yellow, a Mixture of Yellow and Blue will make a Green, Purple and Green will make a Blue, &c.

All Bodies appear of that Colour, whose Rays they reflect most; as a Body appears Red when it reflects most of the Red-making Rays, and absorbs the rest; a Blue or Green Body reflects the Blue or Green-making Rays; and so of the rest.

Of Microscopes and Telescopes.

A Microscope is an optical Instrument used to render Insects and other small Bodies or Objects the more conspicuous,

Fig. 71. The single Microscope, is only a small convex Glass as LS, under which the Object a b is placed in its Focus, and the Eye at or near the same Distance on the other Side; then from what has been already said, and the Figure, it is plain, that the Rays which flow from the Extremities of the Object a b, will enter the Eye in the Lines LE, SE, and consequently will be seen under a greater Angle, and so appear larger than if there had been no Glass.

If you would know how much this Glass magnifies; divide the least Distance at which an Object can be distinctly seen with the naked Eye, by the focal Distance of the Glass, and the Quotient

tient will nearly shew, how much the Glass Magnifies.

Eig. 72. The *Compound Microscope* is generally made of three Glasses which are thus disposed; the Object Glass or *Lens* LS is of about half an Inch or an Inch *Focus*, CD and FG are two Eye Glasses, placed sometimes close together, and sometimes at an Inch or two distant from each other; ba is a small Object placed at a greater Distance from the *Lens* LS than is its principal Focus; so that the Rays flowing from the Object ba through the *Lens* LS, make an inverted Picture at AB, which will be as much larger than the Object, as its Distance from the *Lens* is greater.

The Eye Glasses CD, FG answer the End of a single Microscope: For the Rays which flow from the Ends of the enlarged inverted Object AB will enter the Eye under the Angle CED, which is much greater than the Angle under which they would be seen by the naked Eye; and the Rays which flow from any Point of the Object, will enter the Eye parallel to each other, and therefore will be seen distinctly, by what has been already said.

The *Solar Microscope* is thus made.

Fig. 73. Having made a Room very dark, let a Hole be made in the Window Shutter, of about three Inches in Diameter, so that the Sun may cast a Cylinder of Rays into the Room: In this Hole, place the End of a Tube containing two Glasses and an Object, viz. 1. A convex Glass aa, of about two Inches in Diameter, and of three Inches

Inches Focal Distance, is to be placed at that End of the Tube which is to be put into the Hole. 2. The Object ob being put between two Pieces of Glass is placed about two Inches and an half from the Glass aa. 3. At a little more than an Inch from this Object is placed a small Glass de, of about half an Inch in Diameter and of one Inch Focal Distance.

Things being thus prepared, the Rays which flow from the Object ob will make a large inverted Figure upon a white Paper, of the Object, in most beautiful Colours and prodigiously magnified.

The Tube must be so placed that the Suns Rays Ra, may flow directly through the Glass aa; or else they must be made to pass directly through it, by Means of a plane Mirror, or of a piece of Looking-glass, set angularly towards the Sun, so that the Rays which are reflected by the Looking-glass may pass directly through the Tube, and thence they will transmit the Rays of the Object on the white Paper.

The Common Refracting Telescope is thus constructed

Fig. 74. A is the Object Glass, its Focal Distance Af from One to an Hundred Feet; b, c, d, are three Eye Glasses, whose Focal Distances are from one to ten Inches.

The Glasses being thus prepared let them be placed in a Tube in such a Manner, that the Distance between any two may be equal to the Sum of their Focal Distances, as in the Figure; and

T

the

the Eye must be placed at E one Focal Distance of any of the Eye Glasses, from the outermost one d; then it is plain that the Rays flowing from any vastly distant Object through the Glass A, will make an inverted Figure of it at f; and the Eye Glass b being placed within the Focal Distance of f, and the Eye again at e the same Distance from b, the Picture will be seen distinctly but inverted; so that two other Glasses are used to make it appear erect as before.

The Line mA represents the Axis of a Pencil of Rays flowing from the Top of the Object, and nA one flowing from its Bottom: When they enter the Eye either at e or E, it is plain they converge much more than they did before their Entrance into the Glass, and therefore the Object will be seen under a greater Angle; but the Rays which flow from the same Point of a distant Object, enter the Eye in Lines parallel to each other, and consequently the Object will be seen distinctly.

The magnifying Power of a Telescope is found, by dividing the Distance of the Glass A, by that of any of the other Eye Glasses.

In the *Reflecting Telescope* a concave Mirror is made use of instead of a convex Glass.

The Picture which is made by a convex Glass is always tinged a little with Colours about the Edge; but the Picture made by a concave Mirror will ever be clear; and therefore the reflecting Telescope is preferable to the refracting one, so long as the Mirrors are kept clean.

C H A P. VII.

Of Aerial METEORS in general, and of Aqueous METEORS in particular.

I. *Of Aerial Meteors in general.*

TH E Phœnomena which arise from Bodies that are either suspended, conjoined, or separated in the Atmosphere; or from such as move, ascend, descend, are driven, or set on Fire therein, are called *Meteors*.

Whatever ascends into the Air from the Earth is called a *Vapour* or *Exhalation*: But the constituent Parts of a Vapour are aqueous and moist, and those of an Exhalation are not, for they consist of the subtilest Parts of solid as well as fluid Bodies.

As Vapours and Exhalations which are continually ascending in great Quantities, corrupt the Atmosphere, it therefore follows that various Phœnomena must thence necessarily arise. The Quantity of Water which ascends in the Form of Vapour in one Day exceeds Belief; for in the *Mediterranean* Sea only, Doctor *Halley* by Experiment found, that many Millions of Buts of Water ascended in the Form of Vapour in one Day. Such Parts of the Earths Surface, as are thick with Plants, contribute much to the encrease of Vapours and Exhalations, as do the Perspiration of all Animals, the noxious Fumes arising from

Vegitables and Animals dead and rotting over the whole Earth, and from Bodies burning for daily Use, as well as from burning Mountains, and those earthy Perspirations which are produced from subterraneous Fires, which abound in the Bowels of the Earth, all conspire to supply the Air with a sufficient Fund for the production of Meteors.

Vapours and Exhalations ascend on Account of various Causes of which these are the chief.

1. They ascend by the Means of Fire, whether it be culinary or earthly, subterraneous or solar produced by the Sun. For Fire by entering into Bodies agitates and rarifies their Particles, and with a rapid Motion drives off the most subtile of them with great Force, which being specifically lighter than Air, are by that Means carried up till they meet with lighter Air.

2. Many Bodies being exposed to the same Fire that Air is, receive more of the Fire and retain it longer than the Air can; on this Account the volatile Parts of Bodies on the Earth may be seen on a Summers Evening to rise and form a Vapour over the Ditches and Meadows, because they are more rarified than the Air about them is. Or if on a frosty Evening, a large Aperture be made in Ice, a watry Vapour much warmer than the Air is, will be found to rise in great plenty.

3. The Particles of some Bodies become volatile and are driven upwards, by the Bodies being fermented, putrified, boild or broken: For Bodies which are in any of these States emit much Vapour and Exhalation. That a Body's being seperated or broken

broken may occasion a Volatility in some of the Parts, is plain from a Vapour which arises on the descent of the Water falling from an Height, as at *Powers-court*, or at the *Salmon-leap* near *Leixlip*. In *Canada*, the River *Niagara* falls down a steep Rock 156 Feet, with a Noise which is heard by all the Country round about, and forms a Cloud by the Particles that fly off, rising in the Form of a thick Mist, which may be seen at the Distance of five Miles.

4. Water and other Fluids attract, and are attracted by Air. And therefore the Particles of Water and other Fluids which are attracted by Air, ascend into Air, as soon as they are separated from the Masses to which they belong.

5. Winds raise Vapours from several Bodies, especially from such as are aqueous, and hurry them away. Hence wet Cloths, when exposed to the Wind, are soon dried.

Lastly. Whatever can disunite the rarer Particles of Bodies from the Bodies themselves, or can render the Particles specifically lighter than Air, will be the Cause of their Ascent. If Particles, which are much lighter than Air, meet others heavier than themselves, they will adhere and compose a Mass still lighter than Air, which will continue to ascend on high.

We discover that Vapours issue and ascend from the Earth. 1. When we see the Ground and distant Mountains to throw out a Fume. 2. When the Heads of distant Hills are covered with Clouds though in a serene Sky. 3. When all distant Bodies seem to twinkle. 4. When Mists which are formed

formed by Vapour ascending from Lakes and Marshes, will be seen to hang over them. 5. When the Sun and Moon rising and setting appear very ruddy.

Because the Density as well as the specific Gravity of the Atmosphere differs at different Distances from the Earth's Surface, therefore Vapours and Exhalations may ascend and continue at various Heights in the Air; those that are rarest are driven or carried to the greatest Distances, and those which are nearly as heavy as Air, lie near the Earth, and such as are yet lighter are carried higher into the middle Region of the Air.

Hence Clouds and other Meteors which are formed in the Air, are at different Distances from the Earth, and hence it also is that Vapours and Exhalations will ascend or descend in one and the same Place as the Atmosphere becomes more or less dense.

The more dense the Atmosphere is, the more Vapours and Exhalations is it capable to sustain; and the rarer, the more unfit it is for that Purpose. Now in Winter the cold Atmosphere becomes most dense, as is proved by the Barometer, and consequently is most capable to support the greatest Quantity of Vapours and Exhalations, and therefore in that Season the greatest Number of Meteors happen. And because this Reason chiefly prevails in cold Countries, it is, that more Meteors are observed in them, than in warmer Climates.

Vapours and Exhalations descend to the Earth from the Atmosphere, on Account of various Causes, the chief of which are these.

1. As soon as the Density of the Air, or its Specific Gravity is diminished, the Exhalations will descend by their Gravity, which is manifest from the Barometer. And this may be also proved by covering moist Air with a Receiver: Upon exhausting some Air, a little Cloud is formed under the Receiver, which will fall as the Air is more exhausted or rarified; and hence we observe Rain and other Meteors, when the Mercury in the Barometer is very low, indicate the Air to be very light.

2. When Things which had ascended by being rarified with Fire, lose their Heat, they become condensed and specifically heavier than Air, and so descend.

3. When Things lose the Motion they had received from Fire, or from any other Cause which drove them upwards, they will descend.

4. When Particles are driven by Winds against resisting Obstacles, or against one another by Winds that blow in opposite Directions, or if Particles unite from any other Cause, by this Concourse they become specifically heavier than Air, and therefore descend.

5. When some different Kinds of Exhalations unite, they will excite a boiling Heat or Effervescency with each other, which wearing off, the Body becoming thereby condensed, is precipitated or hurried downwards.

6. Such Particles as are exhaled or carried off in Winds, are with them again driven downwards.

7. Winds which blow horizontally below that Part of the Atmosphere in which Exhalations are suspended, drive the Air away which sustains them, and then they descend in the Place of the Air that was drove away.

8. When more Vapours and Exhalations ascend than the Atmosphere is capable to sustain, those that are superfluous must return back, having lost their Motion by which they ascended.

Meteors may be conveniently divided into three Kinds, *viz.* first, into Aqueous Meteors; secondly, into fiery Meteors; thirdly, into airy Meteors or Winds. These we will treat of severally.

2. Of Watry Meteors, *viz.*

Of Mists, Clouds, Dew, Rain, Frost, Hail, Whirl-wind, Rain-Bow, Halos, Parhelia, Paraselenæ, &c.

A *Mist* or a *Fog* is occasioned by a plenty of Vapours or Exhalations which are suspended in the Atmosphere near the Earth's Surface, and which are constituted, dispersed and ranged in such a Manner as to intercept much Light, and to make the Air darker than usual.

The Vapours and Exhalations that form Mists, ascend slowly from and fall slowly to the Earth; and therefore they seem to be suspended in one Place, and are not easily seen to advance. When

the

the Vapours which compose the Mist are moist and wet, they are neither hurtful to Animals, nor are they offensive to the smell: But such as consist of Exhalations, stink, are hurtful to the Health, and often occasion many Diseases; and others in many Places are of a poisonous and deadly Nature. It is plain that Mists are composed of some other Matter than aqueous Vapours, because when they are dispersed, we often find a thin Skin or Film floating on the Surface of Water over which they were suspended, which is of a reddish and greasy Nature, something like that which Chemists observe when they prepare the Golden Sulphur of Antimony.

Mists are formed in serene calm Weather, and never when there is Wind, for that disperses them. They are generally observed in an Evening, especially if the Sun in the Day has much heated the Earth, which by its setting quickly cools the Air, and occasions the heated Particles of the earthly Bodies to ascend in great Plenty. In *Ireland* this chiefly happens in the Spring, and in the Autumn; because the difference between the Evening Heat and that of the Day is much greater in these Seasons of the Year, than in Summer or Winter: There are also Morning Mists in Winter, about the Time of Sun rising, because then the Air is sooner heated or rarified than the Exhalations which are suspended in it, and therefore they being specifically heavier than Air, descend and cause the Mist: These are often seen in the Winter Months, *November, December, January, February*, and Mists are seldom

dom seen in the Summer Months, for in them the Exhalations are almost as soon heated as the Air in the Morning, and are almost as soon condensed as it is in the Evening: Hence if you do but breath in the Winter, you see a Mist, which consists of heated Vapours from the Lungs into condensed Air, of which there is no Sign in the Summer. In Places therefore which are near the North-pole, they have Mists for several Days together: These usually happen before or after West or South-west Winds, or with an East Wind, but rarely with any other Winds; for they bring with them many Vapours from the Neighbouring Ocean. Mists happen in a hard and continual Frost, and when the Weather is clear and mild.

Mists which continue for several Days successively, are frequently followed by Rain or Snow, the Vapours uniting and forming grosser Bodies by Condensation.

When a thick Mist falls upon the Earth, it moistens it like Rain, for the Vapours are of the same Consistence, and differ only in the Magnitude of their Globules. They are sometimes so subtile that they cannot be perceived, and sometimes as large as small Drops. A Mist falls indifferently upon all Bodies whether rough or polished; if it be very moist it penetrates into Houses, clings to Walls, and runs down in Drops and damps, or moistens all Kind of Furniture.

The Day-light is intercepted by Mists sometimes to a greater and sometimes to a less Degree. The darkness is sometimes so great, that a Person cannot see any Object that is within a few Yards
of

of him. The disorderly Situation of the Particles which compose the Mist, causes Passages of an irregular Figure and Magnitude; on account of the very different Density of the Air and the Exhalations; by this Means the Light is obstructed in its direct Passage, and is drove off to either Side. Hence it is that when the Air appears misty, it soon becomes transparent upon receiving more Vapours which are distributed through it more uniformly.

Sometimes the whole Atmosphere is replete of very thin Mists, through which the Sun may be looked on, without offending the Eyes; but it appears wan or pale, as if it were unable to shoot forth its Beams, and yet the Atmosphere looks as clear as if it were almost in a quite serene and undisturbed State.

Serene Weather follows the Morning Mists in Summer; for they being thin and rare, are readily dispersed, driven or attenuated through the Atmosphere by Means of the Sun's Beams.

Winds by striking against Mountains frequently condense the Vapours they drive forward, and cause sudden Mists to arise at the Mountains.

A Person in a Valley who looks on the Sides of Mountains which are illuminated with the Sun, will observe thick smoaky Mists to arise from them; because the Spectator views the Sun Beams that strike against the Mountain, laterally and obliquely, through which Beams the ascending Vapours may easily be seen; as we see small Particles of Dust floating in the Air in the Sun's

Beams, when we look upon it obliquely or Sideways.

A *Cloud* is nothing but a Mist which has ascended: For Smoak which arises from the burning of any Bodies, forms a Cloud. Many have had the Curiosity to go up into the Clouds, which cover the Tops of Mountains, and have found them to be Mists only; and others have gone to the Tops of Mountains, which were above the Clouds, and have seen the Cloud or Mist under them. Some Travellers have gone into the Clouds on the Tops of the highest Mountains, and yet have found the Clouds were nothing but Mists, which do not consist of Snow, Ice or any firm Body.

Clouds are continually changing their Shape, and therefore it follows that they must consist of thin fluid Exhalations, and not of solid and concrete Bodies; for should Clouds cohere into firm Masses, they would soon become specifically heavier than the Air, and would fall on the Earth, if very rapid Winds did not hurry them away; but as this has not yet happened, the Clouds therefore are not solid, though they seem to be so.

Some Clouds appear to be more opaque, or darker than Mists; and again others are so white, that they seem to be composed of pure Snow, or of some such white and solid Bodies: Yet these different Appearances do not proceed from any Difference in the constituent Parts of either, but because the Spectator is surrounded with a Mist through which he views the Cloud, and therefore

as he then views it through a thicker Medium, it will appear darker, than when he views it after the Mist is dispersed through clear Air; or through a thinner Medium.

Clouds are suspended in the Atmosphere at different Heights, according to their different Specific Gravities; and hence they are seen to move over one another, and though the highest Clouds seem to be at a great Distance from us, yet few of these exceed the Distance of one Mile. Very thin Exhalations may arise to a much greater Height, but on account of their great rarity and transparency they do not appear as Clouds to us.

Because the Air is never quite at rest, the Figure and magnitude of Clouds are constantly changing, some Parts separate, and others approach them; Winds hurry them away with a very great Velocity and often rend them to Pieces and they vanish: Hence when Tempests rage, the Heaven is clear. The Beams of the Sun often attenuate the grosser Vapours which compose the Clouds, and distribute them through other Air, so as they become transparent with it; and Clouds when they are thus dissipating, have been seen to emit Vapours, which appear like a rising Smoak; and Clouds are also dispersed when the Atmosphere becomes more condensed and weighty; for then they ascend, and being carried into purer Air, they are dissolved insensibly.

The Parts which compose a Cloud are not conjoined and united, because the Extremities of Clouds are irregular and uneven: For were they one united Fluid, as they swim in another Fluid, they

they would assume a spherical or globular Figure, which would continue if that Fluid were converted into a Solid.

Clouds are sometimes tinged with various Colours, yet they generally appear white, because their external parts reflect the pure Light of the Sun, not separated in its Colours. There are also Clouds which are brown and black, particularly when it thunders, which absorb the light and reflect but little of it. The Clouds are usually red about the rising and setting of the Sun, which when the Sun is nearer the Horizon appear violet, and afterwards blue, for the Light striking upon the Globules of Vapour, and being by them reflected and refracted, parts into different Colours, according to the various Altitudes of the Sun.

The Clouds descend and gather together as the Atmosphere becomes lighter and make the Heaven dark, which betokeneth Rain; and then the Mercury in the Barometer falls, as hath been already shewn.

The Clouds are of great Use. 1. By conveying Rain to all the Parts of the Earth. 2. By cooling the Earth, and thereby preventing its being parched by the violent Heat of the Sun. 3. They are a principal Cause of Winds. 4. They reflect and refract the Suns Rays in very different Directions, by which Means we see many Bodies, which are not directly illuminated by the Sun.

Dew is occasioned by Steams and Vapours of the Earth which ascend on high like a Mist, and being extremely rare cannot be seen; when these descend

descend to the Earth they leave a light Moisture which we call Dew.

There are Drops of Water found on Plants in the Evening, and Morning which have been supposed to be Dew; but by many accurate Observations, these Drops have been found to be the Sweat of the Plants, which expires through the Orifices of their Vessels. For every Plant emits this Sweat or Dew according to its Nature, or according to the different Situation of its Orifices; and Plants which have been covered with Glasses, or otherwise secured by Vessels which cover them from the Dew, have collected in one Night more Drops than those which have been exposed to the Air and Dew: And it has also been observed, that the Drops are only found where the Orifices of the Vessels are manifestly open, and not all over the Leaf, nor in the hollower Parts of the Plant, which must be if it were produced by the Descent of Dew or Vapour. This Sweat is soon dispersed by the Wind, or by the Heat of the Day, and of a calm hot Day it is emitted copiously from the Vessels.

The Earth is greatly heated by the Sun, which as before, causes many Vapours and Exhalations to arise. Whatever rises in the Day escapes our Sight for the most Part, and is quickly dispersed in the Air: But when the Air cools after Sun set, the warm Steams arise in greater plenty with a slow Motion; by which Means they adhere first to Bodies that are near the Ground, and then to those that are higher: For they have often been

been observed to rise no higher than 31 Feet in an Hour and half.

The ascending Dew must manifestly differ according to the different Soils of Places; as abounding here and there with aqueous, spirituous, oleaginous, saline and metallic Qualities of the Earth's, from whence they arose; and therefore in different Soils it is plain they must produce different Phœnomena, and occasion different Distempers to Animals. Hence Dew never adheres to polished Metals in some Countries, yet in others it adheres to them, so as to rust them daily; and again in other Places, it adheres to all Bodies without Exception.

In some Places the Dew has been found to ascend but not to return, being dissipated by sudden Winds: In other Places it ascends and settles by retaining its Heat; and again much greater Quantities ascend than descend, for the upward Parts are drove forward by Winds, which do not affect the lower.

The Winds, Rains, and other Inconveniencies render it impossible to determine the Quantity of Dew that arises every Night or in a Year, and this must differ with respect to the different Soils, as well as with Respect of the different Degrees of Heat in different Countries.

Oily or Honey-dew is produced by the violent Heat of the Sun on Trees, and Herbs, which emit an oily Sweat, and rising as dew, afterwards falls on Water and makes its Surface appear oily and fat. This may be seen on Rivers near Places where there are many Trees planted.

Rain is a Multitude of Drops which for the most Part fall from Clouds: But in Summer after calm Weather when the Sun is violently hot, small Quantities of Rain fall in small Drops; for the great Heat hurries the Vapours upwards with an uncommon Velocity into cool Air, where being quickly condensed, they return in Drops without forming a Cloud.

When the Particles of Vapour, that form a Cloud, approach each other so nearly as to attract each other, they cohere and form a Drop, which becoming specifically heavier than the Air that before sustained them, falls downward, and meeting other Drops is united with them, and so increases in Magnitude, till it falls on the Earth.

When the Parts of a Cloud are changed equably, but slowly, so that the Vapours unite gradually; then they will fall down in very small Drops, the Specific Gravity of which, do but little exceed that of the ambient Air, and therefore descend through it gently, in Form of every thin dewy Rain called *Pfecas*, or vulgarly a *Scotch Mist*; but these are not very frequent: The like will also happen, when the Cloud first changes its lower Parts, and proceeds gently upwards, for in this Case the Vapours uniting into small Drops will descend gently, and will come to the Earth in the same Magnitude, as when they left the Cloud: But if the upper Part of a Cloud be first changed, it is plain the Drops must increase by attracting Vapours, the further they descend till they fall in large Drops: This is frequent, and a heavy Shower has been observed by some in a Vale, when others

on the adjoining Hill, and in, or under the same Cloud, have found the Shower but light.

Notwithstanding what has been already said concerning Rains, yet the Winds seem to be the principal Cause of them; for when the Wind blows downwards upon a Cloud, it thereby forces the Vapours to unite and to fall in Rain; and vaporous Clouds which arise from the Ocean, are carried by the Winds over terrestrial Regions, and being dashed against Hills, or against other Clouds, which have been driven in an opposite Direction, they are thereby forced into Rain; for Winds which blow between the West and South, or from either the great *Western Ocean*, or from the *Atlantic Ocean*, are generally productive of Rain; but Winds from the Continent, seldom produce Rain, unless they are met with Winds in contrary Directions, and then Rain ensues with us. These Observations or Rules for Rain, are far from being universal, for every Country, from its own Observations, is best able to account for Rains being produced by this or that Wind.

Since the Air is infected with all Kinds of Exhalations, and is defiled with Salts, Spirits, Oils, Earths, Metals, &c. it is plain that Rain in its Descent, must also be defiled by passing through it, and therefore that it cannot be pure Water; and that it must be better or worse as the different Soils are from whence the Exhalations arose, as well as according to the different Seasons of the Year; and because the Seeds of very small Plants, and the Eggs of innumerable Insects float in the Air, they must be carried down with the Rain.

Hence

Hence it is that Greens of different Kinds, vegetate in Ditches, Ponds, Lakes and Rivers; and that Rain Water is soon corrupted, by the Means of innumerable Animalcula, which quickly die and stink.

If Rain Water be ever so carefully closed in a Vessel, it will be full of small white Spots or Clouds, from the Quantity of Corpuscles or Animalcula it contains, which by Degrees increase, and the Water will become more opaque. These in a little Time degenerate into a thin, stiff, glutinous *Mucus* or *Muck*, which occasions the Water to be of a ropy Nature.

From what has been said we may partly account for Showers of a miraculous and uncommon Nature; for the several Exhalations came down with them as they fell. *Moses* (in XIX Chap. of *Gen.* and 24th Verse) tells us, it rained Brimstone; and *Scheuch Zerus* relates, that in the Year 1677, there was a yellow Rain fell near *Zurich*, which was found swimming in the Form of Powder upon an adjacent Lake. It was imagined that this Powder was carried by the Wind from the Pines into the Air, where it mingled with Rain.

We have had frequent Accounts both from the Antients and Moderns of *Drops of Blood* falling in Showers: But some curious Persons upon Examination found the Drops were full of Red Insects.

We are also told of a *Salt Shower* occasioned by a raging Tempest at *Sussex* in *England*: (*Philos. Transf.* No. 289) for the Sprays or extream Drops of the Surges of the Sea, which arose from its being

dashed against the Rocks, were carried a loft in the Air, and fell on the adjoining Lands.

Hence therefore it is, that after a Shower of Rain, we plainly discern the Air to be pure and transparent, so that very distant Objects may be seen clearly and distinctly; and that the Colours of Plants are then most bright and beautiful, and that the vegetable and animal World seem to be renewed by the fresh vivifying Air.

Though Rain falls from high Clouds, yet it does not come to the Earth with so great a Velocity as may be expected by the Law of Gravitation, on Account of the great Resistance of the Air. This is so ordered that tender Plants may not suffer by the Drops, which otherwise would be destroyed.

Rain is of Use, to moisten and soften the Earth which is dried up by the Sun, and thereby it becomes fruitful by nourishing all Kinds of Vegetables; it washes and cleanses the Air, from filthy Exhalations, and from the hurtful or useless Respiration of Animals: It cools the Air that is near the Earth, by falling from higher and cooler Air: It is the Origin of Fountains, Springs, Brooks, and therefore of Rivers, but not the only Cause; for the Vapours cooling in the Night unite on the Surfaces of Mountains, and convert into Water, which distilling downwards, supplies Springs and Rivers with an incredible Quantity of Water.

A *Water-spout* or *Whirl-pool* is occasioned by two Winds blowing in opposite Directions, which do not meet with, or touch each other, but leave a Calm between them. Such Winds whirl a Cloud about
that

that falls between them, condense it and roll it into a cylindrical or conical Form, which descends by its Gravity, but its Base still adheres to the remaining thick and black Cloud, and its Vertex is downwards. Water-spouts are of very different thickneses, sometimes they are more than 50 Fathoms, and at other Times not of above 4 or 5 Fathoms.

Water-spouts have been found to be empty within, the Parts receding from the Center, by the centrifugal Force, and the Particles which fly off from the external Surfaces form Rain. They are hurried over Sea and Land. When they are over Sea they sink almost to its Surface, and then by the Pressure of the Atmosphere, Part of the Sea Water rises into the Middle of them, where the Air is rarified by the centrifugal Force of the Water; and light Bodies are seen to rise through the Middle of them. Now because about the arising Column there is a vast Quantity of the Water of the Spout falling on all Sides with Violence on the Sea; it exhibits about the Surface of the Sea, the Appearance of thin Rain, so that the Sea seems to rage and foam. Wherever a Whirl-pool settles, it strips the Ground, destroys and beats down every Thing in its way, as Buildings, Trees, Ships, &c. with more Violence than the most rapid Winds; sending forth a Noise nearly resembling that which is made by a Multitude of Carriages rolling over Pavements, which does not cease till the Cloud is quite fallen down. The greater the Spout is, the sooner it is spent, and the Continuance of any of them is but short,
that

that is, they are not of so long as of an Hours Duration.

Immense Quantities of Water fall upon the Earth when a Cloud breaks, so as to overflow it with immoderate Showers. Indeed when Clouds are squeezed together by Winds, meeting in opposite Directions, or when Winds drive the Clouds with Violence against Mountains, the Clouds break and fall in heavy Rain. Hence Rain is more frequent in hilly or Mountainous, than in flat and champain Countries.

Hoar-frost is a light Dew or Vapour which issuing out of the Vessels of Plants, and from the Earth is soon condensed by the cold Air in the Winter, and being changed into Ice, covers the Face of the Earth and all Things on it that are low.

Hail is nothing else but Drops of Rain which are frozen in their Passage through cold Air, and become hard Bodies; and just as Drops of Rain differ at different Times in their Magnitude, so do Hail-stones also differ in their Size.

Hail-stones are seldom in the Form of a perfect Sphere, but are for the most Part flattened, compressed, full of Angles, concave; and they are generally so, if the Wind blows hard; for they by unequal Pressure compress the Drops of Rain and reduce them into various Figures, which they retain after Congelation, or being frozen.

Sometimes Hail is soft, and its Surface is as if it were sprinkled with Meal: But this being small soon melts, because it falls when the Sky is calm, moist, and warmish.

Hail

Hail has often a white *Nucleus* or *Kernel* in its Middle, which is not transparent, but opaque, being covered with a hard transparent Shell. This *Nucleus* seems to be first produced, and falling into a Drop of Rain is surrounded by it and turned into Ice. This Kind of Hail generally falls in a Mixture of Rain.

Hail sometimes puts on very different Figures, and again every of its Stones or Grains is of the same Figure, which is either pyramidical, half round, full of Angles or squeezed flat; this seems to be occasioned by Exhalations, which are of a different Nature mingling with the Drops, and being turned into Ice, assume different Shapes and Colours; but being of the same Nature will be of the same Figure.

Snow is a Collection of long slender Drops of Vapour, which falling from a Cloud and being congealed, meet each other, and compose various Fleeces of various Magnitudes. Indeed the various Forms of Fleeces are truly wonderful; some being irregular, and others for the most Part being of a regular Form; some are like Spikes crossing each other; others are of a pentagonal or hexagonal Form, with beautiful Branches issuing in great variety from their Centers; others represent the Leaves of Flowers; and again, others are in the Form of Stars. These Differences seem to depend upon the Exhalations, being mingled with Vapours, which in falling from a Cloud are congealed; as Salt dissolved in Water may be crystallized into various Figures; for otherwise it would be difficult to conceive, how all the Fleeces should be formed

formed in the Air at some Times, of the same regular Figure.

Snow just fallen is generally very rare, but large flakey Snow is not so rare; because a Quantity of the latter, will yield more Water than a like Quantity of the former.

If after a great fall of Snow, a Frost comes on and continues with serene Weather, the Snow will by Degrees subside, and continually decrease by Evaporation, 'till at length it vanishes into Air: For the solar Heat continually softens and melts it, and making the dissolved Parts volatile, thus consumes it.

The Fleeces of Snow that fall while a Frost continues are always less than those that fall in warmer Air: For as the Air becomes warmer sometimes Snow and Rain fall together.

Snow is very white and reflects the Light strongly, though every Particle of it is transparent Ice, of which we are confirmed by viewing it through a Microscope. But because there are very irregular Pores between the several *Spicula* or *Darts*, the Light cannot pass through them, but is strongly reflected, as if it were transparent Glass beat to Powder.

Snow preserves the Herbs in Winter, by covering and securing them against the inclemency and severity of the Frost, and supplies Brooks and Rivers: If a sudden Thaw succeeds a great fall of Snow, the Snow-waters from the Mountains swell the Rivers, sometimes so as to overflow the adjacent Lands, and to do much Damage, by sweeping

sweeping away Cattle, Corn, Mills, Bridges or whatsoever else happens to be in its Way.

An *Iris* or *Rain-bow* appears when the Sun shines at the Back of the Spectator, and at the same Time there is a dark Cloud before him, with Rain falling between him and the Cloud.

Sometimes two or three Rain-bows have been seen together, concentric to each other. The internal Bow, which is most lively in its Colours is called *Primary*, the external being more languid, is called *Secondary*; if there is a third it appears extremely languid.

The Order of the Colours in the two Bows is inverted. In the primary counting from the inward Part of the Bow, they follow in this Order; Violet, Purple, Blue, Green, Yellow, Orange, Red; and in the secondary Bow, beginning from the inside as before, you will have Red, Orange, Yellow, Green, Blue, Purple, Violet, being the Colours that are exhibited through a glass Prism as before.

Fig. 75. That the primary Iris may be understood, let a Drop of Rain be represented by BNFG, upon which let AN a Ray of the Sun fall, which is refracted at N to F, where let it go out of the Sphere by Refraction towards V, or be reflected to G, from whence let it go out by Refraction towards R, or be reflected to H, and there let it go out by Refraction towards S, and cut the incident Ray in Y: Let AN and RG be produced till they meet in X.

Parrallel to the incident Ray AN, draw the Diameter BQ, and let BL be a Quadrant next
Y the

the Sun, upon which let us suppose many Rays to fall parallel to AN or BQ: As the Point of Incidence removes from B towards L, the Angle AXR, which is contained by the Rays AN and RG, will increase at first, and then decrease; and on the contrary, the Angle AYS will first decrease and then increase.

Let N be that Point of the Quadrant BL on which, if the incident Ray falls, it makes the greatest Angle possible with the Ray RG, which emerges after one Reflection: Then all the Rays that fall a little on each Side of N, and go out after Reflection, will emerge parallel, or nearly parallel to GR; but those that fall on the Quadrant, at greater Distances from N, though they are parallel before their Incidence, will diverge after their Emergence. Therefore if an Eye be placed in the Direction of the emerging parallel Rays, a distinct Image of the Sun will be seen in the Drop, but if it be placed amongst the diverging Rays, it will not appear in the Drop.

Again if N were that Point of the Quadrant upon which if the incident Ray AN falls, it makes the least Angle with the Ray HS which emerges after two Reflections: Then as before, all the Rays which fall near N, will after two Reflections emerge parallel or nearly so, and will exhibit the Suns Image in the Drop, to an Eye placed in the emerging Rays; but those which fall at a sensible Distance from N, will, after two Reflections, emerge with diverging or scattering Rays, which are too feeble to shew the Suns Image in the Drop, to an Eye which is placed amongst them.

Now

Now, because Rays of different Colours have different Degrees of Refrangebility, the greatest Angle AXR, which can be made by the incident Rays, and those that go out after one Reflection, will be of different Magnitudes, in Rays of different Colours; and the smallest Angle AYS that can be made by the incident Rays, and those that go out after two Reflections, will also be of different Magnitudes in Rays of different Colours; and it has been found, that the greatest Angle AXR is 42 Degrees and two Minutes in Red Rays, which are least refrangible, and the least Angle AYS is 50 Degrees and 57 Minutes; and that the greatest Angle has been found to be 40 Degrees and 17 Minutes in Violet Rays, which are most refrangible, and the least Angle is 54 Degrees and 7 Minutes.

Fig. 76. Through O the Spectators Eye, let OP be drawn parallel to the Suns Rays, and let POE be an Angle of 40 Degrees 17 Minutes, and POF an Angle of 42 Degrees 2 Minutes: POG one of 50 Degrees 57 Minutes, and POH one of 54 Degrees 7 Minutes; if these respective Angles be turned about on their common Side OP, they will describe the Verges of the two Rainbows AFBE, and CHDG.

For the Drop E, and all these in the concave Part of the lesser Rainbow, whose Angle POE is 40 Degrees 17 Minutes, being the greatest Angle in which the most refrangible Rays, can after one Reflection be refracted to the Eye, will strike the Senses with the deepest Violet Colour, in that Region. And the Drop F, as well as all

the other Drops, which are on the convex Part of the lesser Rainbow, whose Angle POF is 42 Degrees 2 Minutes, being the greatest Angle in which the least refrangible Rays after one Reflection meet the Eye, will strike the Senses with the deepest Red Colour in that Region: Therefore all the intermediate Drops between E and F, or between the Concave and convex Parts of the lesser Bow, will exhibit all the intermediate Colours between Violet and Red; so that from the inside to the outside of this Bow, which is the primary Bow, they will be in this Order, Violet, Purple, Blue, Green, Yellow, Orange and Red.

Again, the Angle SGO which is equal to POG, being an Angle of 50 Degrees 57 Minutes, and being the least Angle in which the most refrangible Rays, after two Reflections meet the Eye, the Drop G, and all the other Drops which are on the inside of the greatest Bow, will strike the Senses with the deepest Red in that Region. And the Angle SHO, which is equal to POH of 54 Degrees 7 Minutes, being the least Angle in which the most refrangible Rays after two Reflections, shall meet the Eye; the Drop H, and all the other Drops, which are on the convex Part of the greatest Bow, will strike the Senses with the deepest Violet in that Region. Therefore all the intermediate Drops between G and H, and all the other Drops that are between the inside and the outside of the greatest Bow, will exhibit all the intermediate Colours between Red and Violet; so that the Colours of the secondary Bow, counting from
the

the inside, will be in this Order; Red, Orange, Yellow, Green, Blue, Purple and Violet.

Thus then there are two Bows, a primary and a secondary one, in which the Order of their Colours are inverted; the Breadth of the Primary will be 1 Degree and 45 Minutes, and that of the Secondary, will be 3 Degrees 10 Minutes; and the Distance between the Bows, will be 8 Degrees 55 Minutes.

Hence it must be abundantly manifest, that a greater or less Portion of a Bow must appear, according to the different Height, both of the Sun and the Spectator above the Horizon. For if the Spectator and Sun be both in the Horizon, OP will be parallel to the Horizon; but as the Sun ascends, OP will be depressed, and therefore the Center of the Bow will be below the Horizon, and consequently a less Portion of it can be seen: But when the Sun is 42 Degrees 2 Minutes high, the Line OE will be parallel to the Horizon, and then but a very small Part of an Arch of the Bow will be seen above it; after which if the Sun ascends but a little, the whole Arch or Bow will vanish.

If Rain passes over the Head of a Spectator, who is in the Middle of a Plane, in its Progress many Drops will adhere to Grass and other Plants, and the Legs of the Bow will then seem to cover a large Tract. For the Suns Rays are as well refracted by these Drops, and under the same Angle, as if they were any other Part of the Bow, that is equidistant from the Spectator.

Seeing

Seeing therefore that every Part of a Bow that is equidistant from its Extreame, as well as the Extreame themselves, can only be seen under the same Angles; it must necessarily follow, that a Bow will either appear to move before a Person who goes forward, or to follow one who goes from it.

The Colours of a Bow are more or less intense, as the Cloud before the Spectator is more or less opaque.

In the like Manner the Lunar Iris may be explained, which though very rare, may be observed about the full of the Moon when it rains; it is plain that the Colours of this must be as much fainter than those of the Solar Iris, as the Rays of the Moon are fainter than those of the Sun.

We have shewn that a Bow is equally broad quite through its whole Extent, as it really is; notwithstanding its interior Legs appear broader, and its Top narrower: And hence the two concentric Bows seem to be more distant at their Top, than they are between their Legs: but this is only the Imagination of the Spectator.

Halo's or *Crowns* are luminous Circles, sometimes white, and sometimes coloured as a Rainbow, which surround the Sun, Moon, Planets, and some fixed Stars; of which one, or more concentric to it is seen: Those about the Planets or Stars, or even about the Moon, are not far distant from the Bodies themselves, their Diameters being from 2 to 5 Degrees; but those about the Sun are found to vary in their Diameters from 12
to

to 90 Degrees. The Breadth of the Rings and their Diameters are subject to many Changes.

The intermediate Space between the Luminary and the Crown, is always of a less Degree of Brightness than the Crown or Circle itself; and the Colours of the Crown are more faint and dilute than those of a Rain-bow, and succeed one another in a different Order according to the different Breadth of the Crown. In those Rings Sir ISAAC NEWTON observed, that the Colours in the internal Ring, were Blue within, White in the Middle, and Red without; and that those in the second Ring were Purple, Blue, Green, Yellow, Pale-red; and that those in the third Ring, Pale-blue and Pale-red.

That Part of the Atmosphere which is near the Earth, is the Cause of these Crowns. For our Minds are deceived in falsely judging or supposing the Crowns to be about the Stars themselves, which have either no Atmospheres, or such as are but very small; besides, the Crowns are seen but by a few Observers at once, and seldom at the Distance of two or three Miles; they break and disperse as the Wind rises, and are only collected in calm Weather when the Air is stagnant and sluggish, and when the Heaven is covered with a thin Cloud.

If in cold Weather we make a steam of hot Water to rise between the Eye, and the Flame of a Candle, a Kind of a Crown will be seen in the Steam. Hence it is seen in Baths about a Light. If Air be readmitted into a Glass Receiver, and a Candle be set beyond it, a Crown will be seen

to be about the Flame with several Colours: Wherefore Crowns in the Heavens are produced after the same Manner of some of these artificial ones.

This may arise either from Light passing through the Particles of Vapours; and being twice refracted; or by Light running between the Interstices of Vapours, and being inflected by the attracting Forces, are thereby seperated into Colours. But the former Cause seems to be the more probable of the two.

These Crowns are neither Prognostics of Wind, Rain, or Storms being at Hand, as Doctor *Muschenbroek* asserts from his own Observations.

Parhelii or *Mock-suns* are Meteors which resemble the Sun, and are seen with it and near it. Their Number varies, for from one to six of them have been seen at a Time.

The *Parhelii* seem to be of the same Magnitude with the Sun, but they are not always round; and though they sometimes seem as bright as the Sun, yet they generally are more faint, and if there are many of them to be seen at one Time, some are more dull and pale than others. Their Edges are tinged with Colours like a Rain-bow, and many of them have a long Tail of a fiery Colour, which becomes paler as its Length becomes greater; and others are without a Tail, or have the Tail extended in a white horizontal Circle.

The *Parhelii* are for the most Part attended by Halo's or certain Circles, of which some have the Colours of the Rainbow, and others are white; and these vary both in Number and Magnitude, having

having the same Breadth and apparent Diameter of the Sun: And there are some coloured Circles, which surround the Sun itself, that is, placed in their Center; whose Diameters vary from 45 to 90 Degrees; the Planes of which are perpendicular to right Lines drawn from the Spectator through the Center of the Sun; therefore their Situation must vary, according as the Sun is high or low.

The more lively the Colours of the Parhelii appear, the more languid will be the Light of the Sun. There are besides these Circles, others which are parallel to the Horizon, of which the external one that comprehends all the rest, as well as all the Parhelii is white. *Hevelius* saw one of these, whose Diameter was 130 Degrees. The other Circles which were concentric to this large one, were here and there tinged as they passed over the former coloured ones. Again there were also other Circles situated obliquely, in respect to these; some of which being tinged, had the Order of their Colours, the same as in the Iris; but the inward Part next the Sun, is of the red Colour.

Parhelii have been seen from a Quarter to an whole Hour or two, when the Elevation of the Sun has caused them to vanish.

Because that the coloured Circles or Crowns, which encompass the Parhelii, are in the Air: That the Parhelii never appear but when the Heaven is covered with a thin transparent Cloud: That in as much as the more lively the Colours of the Circles are, by so much the Light of the Sun itself

is diminished: That finding these Parhelii cannot be seen at two Places that are but of a very small Distance at the same Time: That because they are generally observed in Winter when there is Frost, and the Wind at or near the North: And that when they are over, either Snow, Hail or Rain follow; therefore they must be only in the Atmosphere of the Earth.

Seeing the Parhelii do not always produce the same Phænomena, their Causes may be similar, though they may not be exactly the same, therefore we shall shew that something must be changed, when Circumstances vary.]

Let us suppose *Spicula* or *Darts* of Ice, suspended in the Air, which are perfectly fine and Cylindrical, and let these begin to melt before the Sun, so that the middle Part be not yet melted, and that the melted Part may form a small globular transparent Drop, at the Bottom of the Dart, which will adhere to it for some Time, and cause the Dart to float erect in the Air. Now it is plain that when these Darts hang before the Sun, they must intercept Part of its Light, and therefore he will be less resplendent than in a clear Air; and Part of the Suns Rays will be reflected by, and others will be refracted, and pass forwards through them, and will form the white Circle before described, in that Part of the Atmosphere which is Horizontal with the Sun.

If then we conceive these *Spicula* in the white Circle, it is plain that many Rays will be transmitted to a Spectator by the *Spicula* that are placed between him and the Sun, and there will
be

be a certain Place, in which the Spicula will send the refracted Light to the Spectator in the greatest plenty. This occasions a Mock-sun to appear in the white Circle; which may be reflected by the hinder Part of the Spicula, and be seen again in the white Circle &c. and since the neighbouring Spicula always transmit so much the less Light, as they are more remote from the Sun; therefore a shining Tail will seem to adhere to the Parhelii, included in the white Circle. And because of the lateral Rays that are refracted into Colours, the Parhelii and their Tails will be seen with coloured Edges, and the Tails will become least refulgent at their Extremities.

The Parhelii will seem to be in Labour and to loose their Brightness upon the least Motion of the Air. He that is desirous to be fully instructed in the Theory of Crowns and Parhelii, may consult Dr. *Smith's Optics*.

Paraselenæ, or *Mock-moons*, also appear about the Moon with like Tails and coloured Circles as now mentioned in the Parhelii. Their Cause without Doubt is analagous to that of the Parhelii, and their Phœnomena may be explained in the same Manner.

Virgæ or *luminous-Streams* seem sometimes to be emitted by the Sun, through the Clouds, which extend in a conical Form, as far as the Earth. They are generally seen in an Afternoon after hot Weather. They shew themselves when the Clouds prevent us to see the Sun, but the thin and distant Rays are directed to the Earth, through the narrow Interstices of Clouds. These

Rays meet the ascending Vapours, and being viewed laterally affect the Sight, in the same Manner, as when the Sun-Beams are admitted through a Hole in a Window-shutter, into a close Room; we see several Corpuscles or little Bodies floating up and down, and meeting each other in all manner of Directions. But when these Rays which are thus reflected by the Corpuscles, are viewed sideways, they appear in the Form of *Virgæ*.

Having thus explained the principal of the watry Meteors, we proceed now to the fiery ones.



C H A P. VIII.

Of fiery METEORS viz.

Of the Aurora Borealis, Ignis Fatuus, Lament Fire, Bolis, Thunder, and Lightning &c.

FIERY Meteors either emit a faint or rather a shining Light, or they dart out a bright Light and burn. To the first of these belong all Species of the *Auroræ Boreales*, and to the latter Thunder, Lightning, and such like; and of these in their Order.

The *Aurora Borealis* or what is vulgarly called the flashing *Northern Lights* is no new Meteor for it has been described by *Aristotle, Pliny, Seneca*, and others after them. They are not so frequent to those who are remote from the North Pole, as to others nearer to it. And tho' they have not always the same Appearances, but very different ones, yet they are generally in this Manner.

A Cloud is found to appear either in the North or in the North-East, or North-West Parts of the Heaven, which either lies in the Horizon or is elevated above it a few Degrees, seldom so high as 40; or else the Cloud is seperated from the Horizon, so that a blue Sky can be seen between. The Length the Cloud possesses is very variable, sometimes

sometimes taking up but 5 or 6 Degrees, and again extending as far as 100 or more.

The Cloud we here mention is white, and not very bright, but oftner thick and dark: It's upper Limb is for the most Part parallel to the Horizon, yet it is sometimes a little higher in the Middle than at the Sides. Sometimes to the upper Margin of the black Cloud a white and bright Limb has been observed to adhere, that is concentric to it; and this lucid Limb has been observed to adhere to the lower Margin of the black Cloud, when one black Cloud was higher than another. The black Part has been observed to change into a white shining Cloud, after the Aurora has shined for some Time, and has thrown out many flashing Streams; and it then has returned to it's former Opacity. And though the Heaven appears brighter above the upper Limb of the Crown, yet this Brightness is soon changed, by being either increased or diminished.

From the upper Limb, more or less Streams of Light are emitted near one another which are very bright and shining; or they are shining Jets of Fire that become rarer, broader, and less shining, the farther they proceed. When one Jet is dying away, another issues out of the same Limb, which is not so bright, something like Smoak. This again is soon followed by a brighter, which in breaking forth, seems to be choaked or interrupted by some Impediment, and therefore gushes out at Intervals.

This luminous Matter is exploded with great Rapidity, and often increases slowly by Degrees with

with an equable Motion, and becomes the wider, as it continues to rise from the Aperture in the Cloud. Some Jets continue only for 10 or 20 Seconds, and others for 4 or 5 Minutes; but this is not usual; nor are Streams which adhere to the Cloud, with a wider Base and mount upwards in a conical Form.

There are Columns which cannot be seen to issue from a Limb, and therefore seem to be produced from serene Air. Some Columns are perpendicular to the Horizon, others are oblique, others are Arch-ways; and their Lengths are very different: Some shoot from the Cloud with so great a Rapidity as to carry them to the *Zenith*, or Point of the Heaven which is over us; and again, others with a Rapidity still greater, which will carry them far beyond the *Zenith*, almost to the South. They do not always ascend to the *Zenith* directly out of the Cloud, but they are inclined, especially if an illuminated Cloud be suspended in the Middle, between the North and the East, or West.

The lucid Columns contain a white Light, reddish, or blood Colour. As they advance the Colours change so as to resemble the Iris. When several which are emitted from different Parts of the Limb meet in the *Zenith*, they mingle, and form a pretty thick Cloud or Mist, which presently taking Fire, burns furiously, and spreads a green, blue, or purple Light. New Columns soon follow those that went before and vanished, and sometimes they will desist for a few Minutes, before new ones are produced. The lucid Columns
are

are so transparent, that Stars of the first and second Magnitude are seen to shine through them: Indeed they may be sometimes seen through the Limb of a white Cloud, but very seldom through a black one. No sooner several Columns are dispersed insensibly in the Sky, but others often break forth in those Places, where the former ceased. They are sometimes carried in little Clouds, from North to South; therefore after the Meteors cease, great Part of the Sky is filled with thin Clouds.

There will sometimes issue from a Cloud with great Rapidity, a very thin shining Matter, which will not obscure Stars of the sixth Magnitude. This shining Matter comes by Fits, and is more opaque in ascending than in descending, and is thought to be what the Antients called the *Capra Saltans* or the *dancing Goat*; it moves in a very broad Tract, and extends itself far beyond the Zenith. Little lucid Clouds have been seen to break from the Limb of the shining Cloud, and have been carried away from North to South, without any Streams of Light.

All flashing Columns do not seem to issue from a Cloud; for when the whole Horizon is shining with very bright Light, short lucid Columns will be seen to rise therefrom. This may be occasioned by the Cloud which is the Source of Light, being suspended a little below the Horizon; or it must be so small and thin, that it cannot be perceived by the Eye.

This Meteor sometimes appears for a Night, and sometimes for two, three, or more Nights successively.

ſucceſſively. It has been obſerved in one Place, and has not been ſeen from another, of but a few Miles Diſtance. Sometimes there is ſo great a Quantity of it, that it has been ſeen almoſt over all Europe in one and the ſame Time; yet in different Countries it is ſeen with very different Circumſtances. Some *Auroræ* are but of a few Minutes continuance.

The Cloud which is the Source of this Meteor continues unchanged for many Hours, and neither ſeems to riſe above, or to fall towards the Horizon, yet it ſometimes moves from the North towards the Eaſt or Weſt, and ſometimes from the North to the Eaſt and Weſt. It has been ſeen to aſcend above the Horizon, and to be converted into a white ſhining Cloud.

This *Aurora* does not forbode any bad Weather, or dire Calamities, as it is vulgarly ſuppoſed to do; for upon the ſtricteſt and moſt critical Obſervations, neither changes of Winds or of Rains, of Heat or of Cold, of moiſt or of dry, either preſage their coming, or are preſaged by it; nor are they the Sign of Diſeaſes or of Wars.

That the *Aurora Borealis* is in the Atmoſphere of the Earth, may be thus proved.

Since it appears in the form of a Cloud, which is like the other Clouds in the Atmoſphere; ſince the ſhining Cloud continues at the ſame Height above the Horizon for many Hours or Days, and therefore revolves about the Earth's Axis, together with the Earth and the reſt of the Atmoſphere; and ſince the *Aurora* is not ſeen in two different Places at the ſame Time, which are but a few Miles

Distance; it manifestly follows, that it must be within the Atmosphere of the Earth.

The Distance of this Meteor from the Surface of the Earth, has not yet been determined, though often attempted by very good Mathematicians. For we are not certain that it is the same Light that is seen from different Places at the same Time; if we were, by having the different Angles, under which the Top of the Cloud is seen from any two Places whose Distance is known, we could easily determine its Distance from either.

Though the Matter of the *Aurora* is a Fire of such a Nature, as to produce so clear a Light; that Stars may be seen through it; yet who can pretend to assign it's Nature and Properties with safety? Chemists can give numberless Specimens of inflammable and Phosphorean Matter; and Nature has shut up many others in the Bowels of the Earth, which Art cannot arrive to.

The Matter of the *Aurora* seems to expire from the Bowels of the Earth, out of the Northern Quarter thereof: They have been more frequent, and have been found to extend farther than before the Year 1716; for it's Nutriment may have found its Way, by Means of an Earthquake, and when this is consumed, they will perhaps cease for many Ages.

This perspiring Matter ascends, and composes one or more Clouds, which are carried over different Regions, and will not be inflamed till it meets with other Matter, from whence a hot and fiery Effervescence, Steam, or Fume arises, of which many have been discovered by Art. If then a Cloud consisting

consisting of this perspirable Matter, be carried from the North whence it had its Being, by a Northerly Wind to other Distant Regions, and there meets with Exhalations, with which it will cause an Effervescence ; it will be inflamed in that part: Therefore a Spectator who is to the South, or to the South-East, or South-West, of the Effervescence, will have the Light to the North, or to the North-West, or North East of him, bursting forth into Streams and Columns variously situated with respect of the Horizon, and of various Colours; as different Exhalations mingle with the effervescent ones.

The Cloud out of which an *Aurora* rises may continue immoveable for some time in respect to the Horizon, if it be carried with an equal Force from the North towards the South, as that with which the Exhalations are carried from the South towards the North. And many of its Phænomena seem easily explicable, from Sources which may not be far from Truth. Perhaps the Matter it self by falling from the Sky, may furnish an Opportunity for Examination; or Art may prepare something like it, by which it may be known; or its native Place may be discovered in the Surface of the Earth. The Lake *Weter* in *Sweden*, sends forth a Matter not unlike it.

A small fiery Ball resembling a Star, and of the same apparent Magnitude is often seen to move through the Atmosphere in a clear Sky, and to fall on the Earth; and it is called a *Shooting-Star*, or a *Falling-Star*.

These are generally observed in Spring and Autumn in the Night only; and it is not improbable that they float in the Atmosphere and fall also in the Day, though of this we cannot be certain, on account that the Light of the Day obscures them.

They are seen on the Earth to consist of a stiff and clammy Matter, of a waterish Colour inclining to Yellow, and covered with black Spots and have Points on their Surface something resembling these of a Mariners Compass; but they have lost all their inflammable Substance, which when on Fire run through the Tracts in the Atmosphere wherein the inflammable Matter floats.

These Stars may be imitated by Art, thus. If a Ball made with Camphire, Nitre, and earthy Mud, macerated with Spirits of Wine, be set on Fire and thrown into the Air; it will perfectly represent a *Shooting-Star*, with a like remaining tenacious Dreg. Many other like inflammable Substances, are found to be in the Atmosphere.

There is a Phænomenon observed by Sailors at Sea, which is called *Castor* and *Pollux*; it is a small Flame, which adheres to the Masts and Rigging. Of these sometimes two or three may be seen at a Time. Many Sea-faring Persons are so weak, as to think that one of these only is a bad Omen, but that two are propitious, denoting that the Storm will cease. These are little shining Fishes, which being drove up with the Sprays of the Sea, adhere to whatever they fall on, and there shine.

Ignis Fatui or *Wandering Fires* are Phœnomena, which emit Light, resembling that of Bundles of Sticks set on Fire, they are of a round Figure and are about as large as the Flame of a Candle, sometimes they yield a bright Light, at other Times they are more obscure, and of a purple Colour, and they shine least when they are at the least Distance. They are carried through the Air not far from the Surface of the Earth, and are most frequent about Places that are unctuous, muddy, marshy, and about Church Yards, and Dunghills. They are seen at all Seasons of the Year, but they are most conspicuous on dark Nights, and are most frequent in Winter. Sometimes they vanish and suddenly appear in another Place, and they are generally about six Feet from the Ground. They dilate and contract themselves very frequently, and move on in Waves, with Sparks of Fire, but burn Nothing: They follow those that shun them, and shun those that follow them.

Some that have been catched, have been found to consist of a shining, viscous Matter, like the Spawn of Frogs, not hot nor burning, but only shining; so that the Matter seems to be Phosphorus, which is raised and prepared by the Heat of the Sun, from putrified Plants, and Carcasses; which being condensed by the Cold in the Evening, then shines.

These Fires have been said to be evil Spirits, who mislead Travellers out of spite, to plunge themselves into Ditches and Bogs; but this is all mere Fiction.

Lambent Fire is that which sometimes adheres to the Hairs of Children, to adult Persons, and to the Manes of Horses, especially if they are well combed.

These Fires are a real Phosphorus, such as is prepared by Art, from the Parts of Animals. This expiring from the Body, clings to the Hair with the Sweat, and is inflamed by rubbing or combing the Hair. Hence sweaty Workmen, or foul Linen, will shine by rubbing.

Sometimes luminous Tracts appear in the Air which move suddenly from Place to Place, which some imagine to be a Meteor. But this arises from Flies, which fly by Companies in the Night Time, and expire a phosphorean Light from their Bodies.

A *Bolis* is a great fiery Ball which is hurried swiftly through the Air, having generally a Tail. Some have been observed as big as the Moon, and again others, which were but equal to half the Moon's Diameter, illuminated the Earth so strongly by Night, that a Person could see to read by them. One of these as big as the Moon, was found to enlighten the Earth as strongly as a rising Sun does; and in it there appeared to be four Gulphs, which emitted much Smoke, and many little burning Flames were seen on the Ball. Its Tail was seven Times its Diameter.

When Balls of this Kind vanish, a little Ash-Colour sometimes remains behind in the Air. Some advance, and some few appear to stand still, yet they all shine with a brighter Light than that of the Moon.

As a *Bolis* passing over Places, leaves a smell of Sulphur behind it, we may reasonably suppose it chiefly to consist of Sulphureous and other inflammable Exhalations, which are set on Fire by meeting with other Exhalations. The Fluid Matter assuming a globular Form by being in the Fluid Air.

Lightning is a sudden bright Flame, which extends itself every Way to a great Distance in a Moment.

Lightning is seen when the Sky is clear, though not so frequent as when it is cloudy. It happens after hot Weather, and before Thunder, but this generally attends it; and it seldom does Damage to any Things upon the Earth, because it is in high Air.

The Oil of Plants being attenuated by the Sun's Heat, produces Matter for this Fire, and whatever else that is sulphureous or oily, which is dispersed through the Atmosphere, and is set on Fire with it by Turns; and the Flame extends itself on all Sides, as far as the Exhalations are dispersed. Some other Kind of Substances which float in the Atmosphere, take Fire and flash with the rest.

Thunder is a most bright Flame which rises suddenly, and moves with a most rapid Velocity through the Air, according to its Determination. For sometimes it runs upwards, again, horizontally, obliquely, downwards, in Curves, in right Lines, or in serpentine Tracts, and commonly ends with a loud Noise or Ratling.

Thunder

Thunder is seldom known with us before *May*, nor does it continue after *September*; but in the intermediate Months *June*, *July*, *August*, it is most frequent. It comes from every Quarter; but most frequently from the South Wind, and then it is very loud; and almost as frequent and loud, when the Wind blows between the South and East, or between the South and West; and most seldom when the Wind blows from the North, or from between the North and East, or North and West. But these Circumstances are only peculiar to certain Places.

No doubt, Sulphur is the principal inflammatory Ingredient in the Composition for Thunder, because Places that have been struck by it smell strongly of it. The Colour of the Flame, and the cracking and roaring Noise that follows it, shew, that it cannot be Sulphur only; but that it must be impregnated with some other Exhalations, which being set on Fire explode with a Crack.

Art has discovered, that *Balsam of Sulphur* is of the same Nature, when agitated by too much Fire in close Vessels, and then cast out. Such are *Aurum Fulminans*; *Orpiment*, with *Nitre* and *Salt of Tartar*; *Diaphoretic Antimony*, with *Black Soap*; *Pulvis Fulminans*; *Iron* dissolved in *Aqua-Regia*, and mingled with *Salt of Tartar*; *Lead* dissolved in *Spirit of Nitre* &c.

And we know of many other Things, which being set on Fire in a close Place, will flash with a Noise: As *Gunpowder*, *Arsenic* digested with *Spirit of Nitre*; *Geoffrey's Spirit of Nitre* mingled

mingled with any distilled Oil; and also all Oils and *Spirits* which are forced in close Vessels by too vehement a Fire.

Nature no doubt makes Use of many other Exhalations and inflammable Substances mingled with Sulphur to produce the like Effects; and therefore all Thunder will not be the same, but will differ according to the different Exhalations in different Countries.

It is most certain that sulphureous Steams exude from the Earth into the Atmosphere with other Exhalations in every Country, which may enter the Composition of Thunder. Great Plenty of Salts float in the Air, especially the *Matrix* of Nitre, and they impregnate with sulphureous and other Exhalations. These whatever they are, compose the *Matter of Thunder*. This Matter is formed in the Interstices of the Atmosphere in Tracts or Trains, which run in all Manner of Directions; so that when any Part of a Tract or a Train takes Fire, the Flash and Flame will run from one Extream to the other of that Tract, or as far as the Vein of Nourishment leads. Hence the Thunder runs at one Time Horizontally, then upwards, obliquely, downwards and in all Manner of Directions as the Train happens to lie. If a Train were set on Fire at its upward End, the Flame will move downwards, and the Thunder will seem to descend from the Sky.

Thunder therefore is observed to be most frequent in those Places, where the fulmineous Matter expires from the Ground, yet this may be carried to other Countries by the Wind, and there

take Fire. Hence Thunder is much more frequent in some Countries than in others, but most frequent in the hot Countries, whose Soil is parched up by the Sun, whence various Oils and much Sulphur are exhaled. And it happens but seldom in Places, which produce neither Oil nor Sulphur, or in Places that are cold, watry, or moist.

The Flame which begins at one End of a fulmineous Tract, in running through, seems to carry with it, some Parts which could not readily take Fire. When a Quantity of these are accumulated they will in some Time take Fire, and displode with great Violence, and thus the Report or cracking Noise of the *Thunder-clap* is made; for after the Thunder or Flash is ceased, the Thunder-clap soon takes Fire.

It seems probable that some accumulated fulmineous Matter not yet on Fire, form those fiery Balls, which have been observed to fall on the Earth in Places that have been Thunder-struck. For these have heated so afterwards, as to take Fire suddenly through their whole Mass, and by their Displlosion have done much Mischief, and have occasioned great Destruction and Desolation about them. But these Balls are not seen every Time it thunders, for they are either too small or too far off to be always seen, and the Matter of Thunder is different to it.

Though a Thunder-clap is but a single Report, yet it is often heard for 20 or 30 Seconds, with a rumbling muttering Noise, by various Repercussions of the Clouds, Hills, and other Obstacles. Hence in Vales there are long continued bellowing
Thunder-

Thunder-claps; whereas for one Exploſion, it has been obſerved that there is but one Clap. When more fulmineous Tracts than one take Fire, each will end in a Clap, and thus ſeveral Sounds may be heard together, or may quickly ſucceed each other.

From what has been ſaid we may perceive.

1. Why it may fulminate and thunder when the Sky is clear, though this ſeldom happens, yet the ſulphureous Exhalations may always take Fire, as ſoon as they have burſt out of the Earth, whether the Sky be ſerene or cloudy.

2. It is plain that Thunder and Thunder-claps are not always generated in the Clouds, unleſs fulmineous Exhalations aſcend thither; for Thunder has been ſeen to mount from the Earth into the Atmosphere. And the burning Mountain *Veſuvius* has been ſeen to emit Thunder; and ſuch Fires are frequent in Mines, particularly in theſe about *Whitehaven*. But becauſe Lightning immediately follows a Thunder-clap, it is plain, the Noiſe is not in the Clouds, but is excited in that Place where the Thunder ceaſed. This is confirmed by the fulmineous Ball, which excites a Thunder-clap by its Exploſion.

3. Before it begins to fulminate and thunder, the Sky is generally covered with black Clouds, which fly in all Directions before the Thunder begins, as alſo during the Tempeſt; from this Appearance we preſage the coming of Thunder. Theſe ariſe from the Efferveſcency, when they meet with the fulmineous Exhalations, which expel and condense the ſcattered Vapours in
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the Interstices of the Air, into thick and black Clouds; and when these are more compressed by the inflamed Thunder, they are thickened into hard Rain, which generally attends Thunder.

4. The Displosions of Thunder repel the Air from about them on all Sides, with great Violence and cause a Vacuity, into which the Air again rushes when it has recovered its Elasticity. Hence those various Winds and Storms, which usually accompany Thunder.

5. Men and other Animals are frequently killed by Thunder; either through Terror or dreadful Apprehensions which seize them; or they are suffocated by the Spirit of the burning Sulphur, which is a mortal Poison to all Animals; or that the Thunder causes a *Vacuum* in that Place, or at least leaves the Air in it too thin and rare for Respiration; or perhaps all these three Causes concur. Animals that are killed by Thunder, have sometimes deadly Wounds and Contusions, which are conspicuous, but the Cause of their Death is manifest.

6. It is not to be wondered at, that combustible Bodies are set on fire by Thunder; since Thunder is a Flame of fulmineous Matter. That it should melt Metals, that it should rend, beat down, pull up, and cleave Bodies of any Resistance. And since Exhalations are found to penetrate through Wood, Bricks, Walls, &c. it is plain that Thunder being much more subtile, may easily run through Roofs, Ceilings, Floors, &c. If we would know how far we are distant from the Place of Explosion

Explosion, this is easily done by what is said in Page 106.

Thunder and Thunder-claps purifie the Air of its noxious inflammable Exhalations; it moderates the Heat of the Atmosphere, and the Rain that falls at that Time, is thought to be more fertile than other Rain.

Earthquakes are produced by some such Matter as that of Thunder, kindling and taking Fire, in the Bowels of the Earth, where there is little or no Vent, which rushing backwards and forwards, affects the Earth as it were with Convulsions, and causes some Parts of it to shake.

Something resembling an Earthquake may be made by mixing 10 or 15 Pounds of Sulphur, and as much Filings of Iron, and making them into a Kind of Paste with common Water; this being buried under Ground, will in 8 or 10 Hours throw out a Flame, and cause the Earth about it to shake, to a considerable Distance.

Hence we may account for the Fires of Mount *Ætna*, *Vesuvius* and other *Vulcano's*; for it is not improbable that certain metalline and sulphureous Particles were set on Fire under these Mountains, which wanting Vent burst forth, and continue to burn so long as they are supplied with Nourishment. And from such like Causes proceeds the Heat of Bath-water, and other hot Springs.

What has been already said in Pages 102, 103 and 104, may suffice for *Airy-meteors* or *Winds*.

C H A P. IX.

The ELEMENTS of ASTRONOMY.

ASTRONOMY is that Science which explains the Motions, and *Phænomena* or Appearances, of the heavenly Bodies.

The *Copernican System of the Universe*, or that which is generally received, by the latest and most able *Astronomers*, supposes six opaque dark spherical Bodies called *Planets*, which have no immediate Light of their own, but what they borrow from the Sun, to perform their Periods round him at different Distances and in different Times: The Names of these Planets, and the Characters by which they are expressed are these, *Mercury* ☿, *Venus* ♀, the *Earth* ☉, *Mars* ♂, *Jupiter* ♃, and *Saturn* ♄. These all move round the Sun in Orbits which lie in Planes that have but a small Inclination to each other, and these Planes cut one another in Lines, which pass through the Center of the Sun; therefore a Spectator in the Center of the Sun will be in the Plane of each of their Orbits, and will see them revolving round him and performing their Periods from West to East in their stated and appointed Times, according to the Order of the Letters ABCD, in such a Manner as they are represented in *Fig 77*.

Where

Where the Sun is placed in the Center of all their Orbits, and next to him is the Planet *Mercury* ☿, which finishes his Course in 87 Days or about three Months: *Venus* ♀ being next in Order, performs her Period in 224 Days and 17 Hours, or in about $7\frac{1}{2}$ Months; the Planet next in order beyond the Orbit of *Venus* is the *Earth* ☉, which performs its Circuit in 365 Days, 5 Hours, 49 Minutes, or in a Year: Next to the Earth is *Mars* ♂ who takes 686 Days and 23 Hours or about 2 Years to compleat his Circulation; then in an Orbit vastly extended beyond *Mars*, moves *Jupiter* ♃ who compleats his Period in 4322 Days, 12 Hours, or in about 12 Years; and lastly, *Saturn* ♄ which is very far beyond Jupiter, compleats his Revolution in 10759 Days and 7 Hours, or in about 30 Years. Their real Distances from the Sun are nearly expressed in the Scheme.

This was the ancient System which was introduced into *Greece* by *Pythagoras* and his Disciples, who had learned it from the wise Men of the East. 'Tis true, the *Ptolemaic System* which supposes the Earth immoveable, and the heavenly Bodies to revolve about it, was embraced by the Vulgar and illiterate Part of Mankind, yet the Philosophers still retained the true System; till *Aristotle* and some of his followers, not being acquainted with true Philosophy, gave way to the vulgar Opinion that prevailed in favour of the *Ptolemaic System*: So that the ancient System became quite neglected till the Time of *Nicalaus Copernicus*, who by solid Reasons and Arguments, restored it to a more flourishing State than ever, from the
Jaws

Jaws of Death, and perpetual Oblivion: Whence this System is called the *Copernican System*.

These before mentioned Planets *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter* and *Saturn*, are called *Primary Planets*, being first discovered and respecting the Sun as their Center; and of these *Mars*, *Jupiter* and *Saturn* are called *Superior Planets*, because their Orbits are superior to, or beyond the Orbit of the Earth; but *Mercury* and *Venus* are called *Inferior Planets*, because their Orbits are inferior to the Earths Orbit, or between it and the Sun.

After the Invention of Telescopes, the Secondary Planets, with many other unthought Appearances, were observed by *Astronomers*, which wonderfully enlarged the ancient System, and confirmed it by invincible Demonstrations.

Thus it was that the *Secondary Planets*, *Moons*, or *Satellites of Saturn*, and *Jupiter* were found always to attend and revolve about their Primaries, and to respect them as their Centers, as they are carried about the Sun, just as the Moon which attends and revolves about the Earth, respects it in its annual Revolution about the Sun, in about 27 Days and 7 Hours.

Saturn is accompanied with no less than five Satellites or Attendants, which at different Distances move round him in different Times: The Distances of these Bodies from *Saturn*, and their periodical Times are as follow. That which is innermost or nearest to *Saturn* is $4\frac{3}{8}$ of his Semi-diameters from him, and compleats its Revolution in 1 Day 21 Hours; the next is $5\frac{3}{5}$ of *Saturn's* Semi-diameters

Semidiameters distant from the Center, and describes its Orbit in two Days and 17 Hours; the third is at the Distance of 8 Semidiameters and finishes its Revolution in 4 Days 13 Hours; the fourth is at the Distance of 18 Semidiameters from *Saturn*, and finishes its Period in 15 Days 22 Hours; and the fifth and outermost is at the Distance of 54 Semidiameters, and finishes it's Course in 79 Days 8 Hours.

Jupiter has four *Satellites*, which move round him at different Distances, and in different Times; thus the first, or that which is next to *Jupiter* is at $2\frac{1}{2}$ of his own Diameters from his Center, and describes it's Orbit in 1 Day 18 Hours; the second is at the Distance of $4\frac{1}{2}$ Diameters, and performs it's Period in 3 Days and 13 Hours; the third is at the Distance of $7\frac{1}{2}$ Diameters, and performs it's Circuit in 7 Days 4 Hours; and the fourth and last is at the Distance of $12\frac{2}{3}$ Diameters, and compleats it's Revolution in 16 Days 18 Hours.

Besides these Attendants, *Saturn* is peculiarly ornamented with a Ring which surrounds his Middle, without touching his Body, the Diameter of which is more than double that of his Body, and though the thickness of this Ring be but small, yet the Breadth thereof takes up half the Space that is between it's outward Surface and the Body of *Saturn*; the Rest of the Space remaining void; so that sometimes we can see the Heavens between the Ring and the Body.

Galileus, a noble *Italian* Philosopher, who was the first Inventor of Telescopes, was by their Help, the first that observed the *Satellites* of *Jupiter*,

and called them *Medician Stars*, in honour to the Dukes of *Tuscany* of that Name, and Mr. *Cossini* the *French King's Astronomer*, first reached all the rest that have been since discovered.

Far beyond these *Planets* the Heavens are decorated and bespangled with a vast Multitude of fixed Stars, which are so called, because they always keep at the same Distance from each other: The *fixed Stars* are supposed to be of the same Matter with the Sun, and to be made for the same Purposes; that is, that each of them is the Center to a System of Planets, which move round it; and of Course, that the Number of Systems, which are contained in the Heavens, are infinitely more in Number than it is possible for us to conceive.

The foregoing System proved to be the true System.

The first Thing that seems necessary to be proved is, that the inferior Planets *Mercury* and *Venus* revolve about the Sun, and that they are contained within the Orbit of the *Earth*.

Fig. 78. Let S represent the Sun, E the Earth, and let NGFH represent the Orbit of *Venus*; if *Venus* be at F, she will appear to a Spectator on the Earth, to have a full round shining Face; because that half of her which is illuminated by the Sun's Rays, is turned to the Earth; and therefore when *Venus* appears full, she must necessarily be beyond, or above the Sun. When *Venus* is at N, her illuminated Side being necessarily towards the Sun, leaves the darkened Side next the Earth,
and

and then she disappears; and therefore when *Venus* disappears she must be between the Sun and the Earth, or the Sun must be beyond or above her; When *Venus* is at H near the Place of her Change, she will appear like an horned Moon, and when she is at G, she will appear to have a Gibbous or humped Form; in short *Venus* in one Revolution round her Orbit, will assume all the *Phases* of the Moon.

Mr. *Horrox* in the Year 1639 with his Telescope, observed *Venus* upon the Disk or Face of the Sun; and the *Phases* of *Venus* may easily be seen by help of a Telescope.

Since therefore *Venus* has those Appearances, that is, since she has a superior Conjunction with the Sun at F, an inferior Conjunction with him at N, since she is, horned at H and Gibbous at G, she must necessarily move round the Sun, and the Earth must be withoutside of her Orbit; for were the Earth withinside of her Orbit, her Appearances would be very different from what they really are, for she would then never appear horned.

Besides *Venus* is observed to keep always near the Sun, for she is never found to be above 45 Degrees from him; so that she never comes in Opposition to the Sun, or to be seen in the *East*, when the Sun is in the *West*; nay she can never arrive at a quartile Aspect with him, or to have one fourth Part of the Heavens between them, which must necessarily happen if she moved round the Earth, either in a longer or shorter Time than the Sun.

Mercury is observed to keep nearer the Sun than *Venus*, and never to recede from him so much as she does; from his Proximity to the Sun, he is generally hid in the Sun's Rays, so that he is to be but seldom seen; he has been observed since the Invention of Telescopes, to appear like a Spot on the Sun's Disk. The extraordinary Brightness by which *Mercury* out-shines all the Planets, is a strong Confirmation that he is nearer the Sun than they; for the nearer any Body is to the Sun, the more it must be illustrated.

Hence it is evident that *Mercury* moves round the Sun in an Orbit which is included within the Orbit of *Venus*.

Having now shewn that *Mercury* and *Venus* revolve about the Sun, and that they are contained within the Orbit of the Earth; we will next proceed to prove that the superior Planets *Mars*, *Jupiter* and *Saturn* revolve also round the Sun, and that the Earth's Orbit is contained within the Orbit of *Mars*.

Fig. 79. Let S represent the Sun, E the Earth, and the Circle ABCD the Orbit of *Mars*; it is plain that when *Mars* is at A or at C, that his enlightened Hemisphere is turned towards the Earth, and so he must shine with a full Face, upon the Inhabitants of the Earth; but at B and at D he will appear a little Gibbous or not quite full. Besides when *Mars* is seen at C or in Opposition to the Earth, he appears to be almost seven Times larger in Diameter than when he is at A or in Conjunction with the Sun, and therefore he must be almost seven Times nearer the Earth in one Position

Position than in the other: Hence it is plain, that not only the Earth lies within the Orbit of *Mars*, but that it is far removed from the Center of his Orbit; therefore it cannot respect the Earth as a Center, but the Sun; for by this Hypothesis only, the Phænomena of *Mars* can be accounted for.

In the same Manner we account for the Appearances of *Jupiter* and *Saturn*, tho' the Proportion of the Difference of the Distances in *Jupiter* between the Earth, and he when in Opposition, is not so great as between *Mars* and the Earth, when they are also in Opposition; now did *Mars* as well as *Jupiter* and *Saturn* respect the Earth as a Center, they would seem to move uniformly and regularly round their Orbits; but they do not seem to move regularly, but to be sometimes slow in their Motion, at other Times quicker, and sometimes to stand still, and at other Times to move backwards, which could never happen, if they respected the Earth as a Center, as will be more fully and particularly explained hereafter; but upon supposing or making the Sun their Center, all these Phænomena can readily be accounted for.

All that now remains to be proved is, that the Earth moves round the Sun, as the rest have been proved to do.

We have demonstrated that the Earth is without the Orbit of *Venus*, and within that of *Mars*; from whence it will follow, that the Earth revolves about the Sun; for if it stood still, seeing it lies within the Orbits of the superior Planets *Mars*, *Jupiter* and *Saturn*, their Motions might appear to be unequal and irregular, but they would

would never appear to move backwards, or to stand still; which may be easily conceived by the help of the Scheme. And as the Earth lies between *Venus* and *Mars*, so is its Period round the Sun is also between the Periods of *Venus* and *Mars*, as being greater than the one and less than the other; whence we have Reason to conclude that the Earth moves round the Sun.

Common Observations convince us, that either the Earth moves about the Sun, or the Sun about the Earth, in such a Manner as to *describe equal Areas in equal Times*: But Sir ISAAC NEWTON has demonstrated, that whenever Bodies are regulated by that Law, the one must gravitate the other; and therefore if the Sun in its Motion, gravitates the Earth, Action and Reaction being equal and contrary, the Earth must also gravitate the Sun: He has also demonstrated that when two Bodies gravitate each other, without directly approaching each other in Right Lines, they must both of them move round their common Center of Gravity; therefore the Sun and Earth, turn round their common Center of Gravity. But the Earth being only as a Point when compared to the Sun, their common Center of Gravity will not only fall within the Sun's Center, but very near it: The Earth therefore turns round a Point, that is within the Body of the Sun, and therefore turns round the Sun. This physical Argument is looked upon to be unanswerable.

By comparing the Periods of the Planets, and their Distances from the Sun to each other we find, that the nearer any Planet is to the Sun the
sooner

sooner does it revolve through it's Orbit, and it's Motion is the quicker; this Observation no doubt, set the sagacious *Kepler* upon investigating his great Law of Nature, concerning the primary Planets, viz. *That the Squares of their periodical Times, are as the Cubes of their Distances from the Sun*; and though he found this Law to obtain in the primary Planets only, yet *Astronomers* found that the secondary Planets were regulated in their Periods and Distances from the primary ones they respected, by the same immutable Law.

It is not easy to conceive how *Kepler* hit upon this Law; for though he discovered it to obtain, yet he was unable to demonstrate it's proper Cause, or to deduce the physical necessity of such a Law; this Task was reserved for the great *Sir Isaac Newton*, who has demonstrated, that without a total Subversion of the Laws of Nature, no other Rule could take Place.

Were the Sun to revolve about the Earth, this universal Law would thereby be violated, the Harmony and Proportion of the Motions destroyed, and the whole Frame of the Earth be rendered an Heap of Confusion and Disorder; but by the Earth's Motion round the Sun, a perfect Harmony is preserved through the whole Frame of Nature.

Of the *Rotation* of the *Sun* and *Planets* round their *Axes*.

If the *Sun* were equally bright in all it's Parts, it would be impossible to perceive that it had
any

any Motion round its *Axis*; but from the Motion of certain black Spots that are on his Disk or Face, the Rotation round his *Axis*, has been discovered to be performed in 25 Days; thus a certain Spot has been observed to appear on his western Margin, and by Degrees to creep near the middle or center of the Disk, and so on, to the eastern Margin, where it has set or disappeared in $12\frac{1}{2}$ Days, and in $12\frac{1}{2}$ Days more, the Spot has been found again to appear on its western Limb.

If the Motion of the solar Spots from *West* to *East*, seemed to describe right Lines, we might conclude that the *Sun's Axis* would be perpendicular to the Plane of the *Earth's Orbit*, which is called the Plane of the *Ecliptic*: Now since the Spots do not seem to describe right, but curved Lines, therefore the *Sun's Axis* is not perpendicular to the Plane of the *Ecliptic*, but deviates from a Perpendicular thereto, in an Angle of about seven Degrees.

Jupiter, Mars and *Venus* have also remarkable Spots upon them, when looked at through a Telescope; and it is by the Motions of these Spots, as with those of the Sun, we conclude that they revolve round their *Axes*: By this Means *Venus* is found to perform her Revolution about her *Axis* in 23 Hours: *Mars* performs his Rotation about his *Axis* in 24 Hours and 40 Minutes. The *Earth* in a Day, which we are confirmed in, by the apparent Revolution of the fixed Stars about it in that Time.

Jupiter, besides having many Spots on his Disk, seems to be circumscribed with certain Zones, Belts,

Belts, or Girdles, which are parallel to each other; yet their Distances from each other are found sometimes to recede, and at other Times to approach. In the Year 1665 Mr. *Cassini* discovered a large Spot on the Disk of *Jupiter*, by which he found that *Jupiter* revolved round his *Axis* in nine Hours and 56 Minutes, or nearly in 10 Hours.

Whether either *Mercury*, or *Saturn* revolve round their *Axes* is uncertain; because the former is so hid by the Sun's Rays, and the latter is so remote, that the Spots if any, upon either, are not to be discovered: Yet we may probably conclude, that they as well as the other Planets, move round their *Axes*, in order that all Parts of their Surface may be cherished with the *Sun's* Rays.

Of the *annual* and *diurnal* Motions of the *Earth*, whereby the *Seasons* of the *Year*, the *Vicissitudes* of *Day* and *Night*, and the rest of the celestial *Phænomena*, which arise from the apparent Motion of the *Sun*, are fully explained.

Having taken a cursory View of the *Universe*, it will here be necessary to consider the *Earth's* Motion more particularly.

Fig. 80. Let *S* represent the *Sun*, *ABCD* the Orbit of the *Earth*, Let the Surface of the Paper represent the *Plane of the Ecliptic*, or that Plane on which the *Earth* moves, and let $\gamma, \odot, \alpha, \nu$, be the Heaven of the fixed *Stars*; then if we suppose a Spectator to be placed in *S*, the Center of the

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Sun, and thence to view the Earth in the Point A of its Orbit, it is manifest that it must appear to him to be at the fixed *Star* γ ; and while the Earth is moving from the Point A to the Point B of its Orbit, that it must appear to him to have moved through the fixed *Stars* γ δ Π and that it is now arrived at the *Star* \mathfrak{S} ; and while it is moving from B to C, that it must appear to have passed by the fixed *Stars* \mathfrak{S} Ω \mathfrak{M} and so to \mathfrak{N} ; in moving from C to D, it seems to pass by \mathfrak{N} \mathfrak{M} \mathfrak{T} and so to \mathfrak{V} ; and in moving from D to A, it seems to pass by \mathfrak{V} \mathfrak{X} and so to γ .

Now let the Spectator be removed from the *Sun* to the *Earth*; then its plain when the *Earth* is in the Point A of its Orbit, that the Observer will see the *Sun* S in the opposite Point of the Heavens at the fixed *Star* \mathfrak{N} ; and that while the *Earth* is moving in it's Orbit from A to B, that the *Sun* will appear to have moved from \mathfrak{N} through \mathfrak{M} and \mathfrak{T} and so to \mathfrak{V} ; also while the *Earth* is moving from B to C, the *Sun* will appear to have moved from \mathfrak{V} through \mathfrak{X} and \mathfrak{S} and so to γ ; and in like Manner while the *Earth* moves from C to D and so to A, the *Sun* will appear to have moved thro' the *Stars* γ δ Π \mathfrak{S} Ω \mathfrak{M} and so to \mathfrak{N} . Therefore the *Sun* to an Inhabitant of the *Earth*, will appear to pass over the same fixed *Stars*, and in the same Order from *West* to *East*, as the *Earth* must appear to have passed over if viewed from the *Sun*.

Hence arises the apparent Motion of the *Sun* from *West* to *East*; thus, if a *Star* be found to rise with the *Sun*, a few days after it will rise be-

fore

fore the *Sun*; and a *Star* which is near the *Sun's* Path will be found to be a little above the Horizon after *Sun-setting*, but in some Time after, it will set with the *Sun*.

In like Manner if the *Sun* were viewed from any of the other Planets, it would seem to move from *West* to *East*, and to describe the same Orbit in the Heavens, or to pass by the same fixed *Stars*, that the Planet would appear to do to an Observer in the *Sun*.

If the Plane of the *Earth's* Orbit ABCD be conceived to extend to the Heavens, it will there lay out the *Ecliptic* $\gamma \epsilon \zeta \nu \varsigma$ or that Circle which the *Sun* appears to describe in a Year if viewed from the *Earth*, or that the *Earth* would appear to describe if viewed from the *Sun*.

Astronomers, have divided this Circle into 12 equal Parts called Signs, which they have named after the Constellations which were then near them; so that each Sign contains the 12th Part of 360, or 30 Degrees.

The Characters and Names by which the Signs are expressed, are these.

γ	ϵ	Π	ϵ	Ω	ν	ζ
<i>Aries</i> ,	<i>Taurus</i> ,	<i>Gemini</i> ,	<i>Cancer</i> ,	<i>Leo</i> ,	<i>Virgo</i> ,	<i>Libra</i> ,
ι	τ	\wp	\approx	\times		
<i>Scorpio</i> ,	<i>Sagittarius</i> ,	<i>Capricornus</i> ,	<i>Aquarius</i> ,	<i>Pisces</i> .		

Besides this *annual* Motion of the *Earth*, it has also a *diurnal* Motion, or one in 24 Hours from *West* to *East*: The two Points where the *Axis* meets

D d 2 the

the Surface of the *Earth* are called it's *Poles*; and if the *Axis* be continued to the Heavens it will there point out the *Celestial Poles*: Every Point on the *Earth's* Surface except the *Poles* will describe a Circle; and that Circle which is described by a Point that is equally distant from the *Poles*, is a great Circle called the *Equator* or *Equinoctial Circle*; but those Circles which are described by any other Points nearer to the *Poles* are lesser Circles, and are called *Parallels of Latitude*.

If a Plane, which touches that Part of the *Earth* where a Spectator stands, be continued on all Sides to the Heavens; it will there mark out a Circle that is called the *Sensible Horizon*. which will separate the Visible from the Invisible part of the Heavens; but if a Plane passing through the *Earth's* Center parallel to the sensible Horizon, be continued on all Sides to the Heavens, it will there mark out a Circle which is called the *Rational Horizon*. But though these two Circles are distant from each other by the *Earth's* Semidiameter, yet in the Heavens they may be said to coincide, in as much as, that Semidiameter is but a Point in Comparison of the great Distance of the Heavens.

Since the *Earth* turns upon it's *Axis* from *West* to *East*, a Spectator on it's Surface, must be carried the same way; therefore all heavenly Bodies which are beneath the eastern Edge of the *Horizon* will become Visible in as much as the Plane of the *Horizon* subsides, being carried to the Eastward with the Observer: and all heavenly Bodies, which are seen above the western Edge of the
Horizon,

Horizon, will become invifible, becaufe that part of the plane of the *Horizon* will Rife as the Earth is carried Eaſtwardly. Hence it is that all the Heavenly Bodies ſeem to move from *East* to *West* and to deſcribe a greater or a leſſer Circle, except theſe Points that are the Celeſtial Poles.

If the Plane of the *Earth's Equator* coincided with the Plane of the *Ecliptic*, then the *Earth's Axis* would be perpendicular to both Planes, and in that Caſe the *Sun's* Rays would enlighten one half of the *Earth* from Pole to Pole, while the other half would remain in darkneſs. ſo that one half of each parallel Circle on the *Earth's* Surface muſt be always enlightened, and the other half muſt remain dark; and therefore by the *Earth's* Verticity, all it's Inhabitants would have a conſtant Equallity of Day and Night, or 12 Hours each; and at the *Poles* they would have half the *Sun's* Body conſtantly appearing to move round their *Horizon*: Seeing then that the Days and Nights are not equal, the *Axis* of the *Earth* is not perpendicular to the Plane of the *Ecliptic*, but it is inclined thereto, at an Angle of $66\frac{1}{2}$ Degrees, and conſequently the Plane of the *Equator* muſt be inclined to that of the *Ecliptic*, at an Angle of $23\frac{1}{2}$ Degrees, the Complement of the former. The *Earth's Axis* alſo in it's annual Motion round the *Sun* keeps always parallel to it ſelf; that is, if a Line be drawn parallel to the *Axis* while it is in any one Poſition, the *Axis* will be always parallel to that Line in whatever Part of it's Orbit it be; at leaſt for a Year or two, the difference is inſenſible: And this muſt neceſſarily be, if the *Earth* had

had no other Motion than it's annual *Progressive* one round the *Sun*, and its diurnal one round it's *Axis*.

Fig. 81. For let PEPQ be any spherical Body whose Center moves along the Line AB, and while it is at A let it's *Axis* Pp be inclined to the Line AB. Now it's plain if the Body by it's progressive Motion only, were carried to B, that it's *Axis* Pp will still be parallel to it's former Position, while at A; and if the same Body be supposed to move continually about it's *Axis*, though all the Parts of it's Surface except the *Poles* will change their Situations, yet the Inclination of the *Axis* can never be disturbed thereby.

Since the Plane of the *Equator* is inclined to that of the *Ecliptic* at an Angle of $23\frac{1}{2}$ Degrees, they must cut one another in a Right Line, passing through the Centers of the *Sun* and *Earth*; which right Line or common Section will remain parallel to it self, because that the *Earth's Axis* preserves a Parallelism, and that the same right Line is always inclined to the *Axis* of the *Earth* at the same Angle. And that Circle upon the *Earth's* Surface which is made by the Intersection of the two Planes, will point out the Path of the *Sun* in his annual Motion.

If a perpendicular Line be drawn from the Center of the *Sun* to the Plane of the *Ecliptic*, and if it be continued on both Sides to the Heavens; this Line will be the *Axis*, and it's Extremities will be the *Poles of the Ecliptic*.

That great Circle which passes through the celestial *Poles*, and the Points of Intersection of the *Equator* and *Ecliptic* is called the *Equinoctial Colure*

Colure; and that other great Circle which is at right Angles with it, is called the *Solstitial Colure*, and this will be found to pass through those Points where the *Equator* and *Ecliptic* are widest asunder: The four Points in which these *Colures* cut the *Ecliptic*, are called the four *Cardinal Points*, because when the *Sun* is seen in them, he determines the four Seasons of the Year: The Points of Intersection of the *Equinoctial Colure* with the *Ecliptic*, are called *Equinoctial Points*; because when the *Sun* is in either of them, all the Inhabitants of the *Earth* enjoy equal Day and Night: And the Points of Intersection of the *Solstitial Colure* with the *Ecliptic*, are called *Solstitial Points*; because when the *Sun* is in either of them, he is then at his greatest Distance from the *Equator*, and seems to stand before he begins to return again.

To explain the *Phænomena* or Appearances that arise from the *Earth's* annual Motion round the *Sun*, we suppose the Spectator to be far removed without the *Earth's* Orbit, so as to observe all those Appearances which we here give a perspective View of: Thus, *Fig. 82.* let S represent the *Sun*, $\gamma \odot \approx \psi$ the *Earth's* Orbit on the Plane of the *Ecliptic*; through S let the Line $\gamma S \approx$ be drawn parallel to the common Intersection of the *Ecliptic* and *Equator*, and to it at right Angles, let the Line $\odot S \psi$ be drawn; then it's plain, when the *Earth* is in the Point \approx , that the Line $S \approx$ connecting the Centers of the *Sun* and *Earth* will coincide with the common Intersection of the *Ecliptic* and *Equator*, and so lie in the plane of the *Equator*, and therefore will be perpendicular

to the *Earth's Axis*; but the same Line is perpendicular to the Circle that bounds Light and Darkness, and therefore the *Axis* of the *Earth* will be in the Plane of that Circle, and so it will pass through the *Poles* of the *Earth*, and cut the *Equator* and all it's *Parallels* into equal Parts. Also the *Sun* will appear in the opposite Point of it's Orbit at γ or in $\approx S$ produced, that is, in the Plane of the *Equator*; and consequently will describe the *Celestial Equator* by it's apparent daily Motion. And since in this Position of the *Earth* the *Sun* will enlighten it from *Pole* to *Pole*, so by it's Verticity, all Persons on it's Surface will enjoy equal Day and Night; and hence the Circle which the *Sun* seems to describe, that Day is called the *Equinoctial Circle*.

The *Earth* by it's annual Motion being carried through the Signs \mathfrak{m} \mathfrak{r} , the Line intersecting the Planes of the *Ecliptic* and *Equator*, remaining always parallel to it self, cannot now pass through the *Sun*; but when the *Earth* has arrived at \wp it will make a right Angle with $S\wp$, which connects the Centers of the *Sun* and *Earth*: And seeing the said Line $S\gamma S$ is not in the Plane of the *Equator*, but in that of the *Ecliptic*, the Angle $P\gamma S$, which the *Axis* of the *Earth* Ps makes with it, will be an acute Angle of $66\frac{1}{2}$ Degrees, or the like Number of Degrees that the *Earth's Axis* is inclined to the Plane of the *Ecliptic*. Let the Angle $S\wp B$ be a right Angle, then the Circle bounding Light and Darkness will pass through B , and the Arch BP will be $23\frac{1}{2}$ Degrees, the Complement of PC , or of the Angle $P\wp S$. Through the Center \wp
let

let EQ be drawn perpendicular to the *Axis* Ps, and it will be in the Plane of the *Equator*; then if from equal Arches or Quadrants PE and BC, the common Arch PC be taken, there will remain CE equal to PB equal to $23\frac{1}{2}$ Degrees. Make Ec equal to EC, and to the *Equator* through C and c, let the parallel Circles CD, cd be drawn; the first is called the *Tropic of Cancer*, and the other the *Tropic of Capricorn*, and the Circle in the Heavens which is concentric to CD is called the *Celestial Tropic of Cancer*, because the Sun appears to be then in ☊. When the Earth is in this Situation, the Circle Bw a, bounding Light and Darkness, will pass $23\frac{1}{2}$ Degrees beyond the North Pole P, or as far as B, and consequently the South Pole must be so far from a, in the darkened Hemisphere: To the Equator let the parallel Circles BA, ab, be drawn through the Points B and a, and these are called *Polar Circles*; that towards the North is called the *Artic Circle*, and the other that is towards the South, is called the *Antartic Circle*.

Now since the *Earth* moves about its *Axis* Ps, it is plain that those Inhabitants of it, who live within the *Artic Circle* AB, will at that Time, have continual Day; and on the contrary, those Inhabitants, if any, who live within the *Antartic Circle* ab, will then have continual Night. Also that such as live under the *Tropic of Cancer*, or on the Parallel CD, will have the Sun Vertical to them, when any particular Place in that Parallel comes to the Meridian at C; and seeing all the Parallels between the *Equator* and the *Artic Circle* are cur

by the Circle bounding Light and Darkneſs, into unequal Portions, leaving a greater Portion of every Parallel in the Light, than in the Darkneſs; therefore the Inhabitants in the *Northern Hemisphere* will then have their Days at the longeſt, and to them the Season of the Year will be Summer; but on the contrary, thoſe in the *Southern Hemisphere*, will have their Nights at the longeſt, and to them it will be the Winter Season; and it is eaſy to conceive that according as one Place is more on the North ſide of the *Equator* than another, that the Day will be longer in the former than in the latter Place; and ſeeing that none of the Parallels, but the *Equator* only, is cut equally by the Circle bounding Light and Darkneſs, therefore it is only thoſe Inhabitants who live in the *Equator*, that have their Days and Nights equal throughout the Year.

The *Earth* being ſtill carried forward in its Orbit from ψ by \approx and \times to γ , in which Time the *Sun* will ſeem to move through the Signs \odot \cap ♊ and by Degrees to return again towards the *Equator*; and the *Earth* being arrived at γ , the *Sun* will appear to be at \approx ; where the common Interſection of the *Ecliptic* and *Equator* ſtill remaining parallel to the Line \approx SV, will paſs through the Center of the *Sun*, and then the *Sun* will appear in the celeftial *Equator*. And therefore the Day and Night will again be equal to all the Inhabitants of the *Earth*, in the ſame Way as when the *Earth* was at \approx , for in this Situation the Circle bounding Light and Darkneſs, will again paſs through the two Poles.

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The *Earth* moving on through the Signs γ, δ, π , the *Sun* will appear to move through α, μ, f , gradually declining from the *Equator* towards the *South*; so that when the *Earth* has arrived at δ , the *Sun* will appear to be at γ . And because the *Axis* of the *Earth* preserves it's Parallelism, the *Earth* will have the same Appearance in respect to the *Sun*, that it had when it was in γ ; but with this Difference, that the Tract within the *Polar Circle* AB, which was in continual Light when the *Earth* was at γ , is by it's being remov'd to δ in continual Darknes, and all that Part within the *Polar Circle* ab, that before was in continual Darknes, is now in continual Light; also such as live under the *Tropic of Capricorn* or on the Parallel cd will have the *Sun* Vertical to them, when any particular Place in that parallel, comes to the Meridian at d; and those in the *Southern Hemisphere* will have their Days at the longest, but those in the *Northern Hemisphere* will have their Nights at the longest; therefore it will then be Summer to the former, and Winter to the latter: And the further any Place is to the South, the Day will be longer, because the Circle bounding Light and Darknes, leaves a greater Portion of every Parallel in the *Southern Hemisphere* in Light, than in Darknes; and since the *Equator* is only bisected by that Circle, the Inhabitants who live in it, are those that only have their Days and Nights equal as before.

All we have said will be much more evident than it is possible for Words to express, from a bare View of the Orrery, by a *Lamp* being fixed

as the *Sun* in it's Center; or in Lieu thereof, if a Candle be lighted in a dark Room, and fixed in the Center of a round Table, and if we take a small Globe of Ivory, of about one or two Inches in Diameter, on which the *Poles*, *Tropics*, *Polar Circles*, and the *Equator* are marked and laid out, and if we carry it with it's *Axis* inclined to the *Table*, or to the Plane of the *Ecliptic* in an Angle of $66\frac{1}{2}$ Degrees; the *Phænomena* before set forth, will very abundantly appear.

By the same Way of reasoning, the *Phænomena* arising from the Circuit of any other *Planet* that turns round it's *Axis*, may be easily accounted for.

If a Line passing through the Center of the *Sun* perpendicular to the Plane of the *Ecliptic*, be continued to the Heavens both Ways, it will there point out the *Cælestial Poles* as before. Now if great Circles are supposed to pass through these *Poles* by every *Star* or *Planet*, these Circles which are called *Secondaries of the Ecliptic*, will be all perpendicular to the Plane of the *Ecliptic*; and on them is measured the *Latitude* of any heavenly Body, or it's Distance from the Plane of the *Ecliptic*, which will be *North* or *South*, as it lies on the one or the other Side of the *Ecliptic*: Also an Arch of the *Ecliptic*, which is contained between the Point γ , and the *Secondary* passing through the Body; will be the *Longitude* of that Body: And if there be Circles supposed to pass through every Place, or Spot on the *Earth's* Surface from *Pole* to *Pole*, such Circles are called *Meridians*: Upon the one of these Circles that passes through any given Place,

Place, is the *Latitude* of that Place measured from the *Equator*; and its *Longitude* is an Arch of the *Equator*, intercepted sometimes between a *Meridian* passing through any particular *Metropolis*, from whence their Inhabitants are pleased to count their *Longitude*, or sometimes from the *Meridian* passing through the Point *Aries*, where the *Equator* and *Ecliptic* first intersect each other, and the *Meridian* passing through the Place.

Fig. 83. Since the *Earth's Axis* retains its Parallelism, it is plain, that when the *Earth* is at different Points in its Orbit, its *Axis* must point towards different fixed *Stars*; thus if the *Earth* be at A, and it's *Axis* points to the fixed *Star* E, when it has arrived to the opposite Part of it's Orbit at B, it's *Axis* will not point to the same fixed *Star* E, but to some other as F, and the Angle EBF which we suppose possible to be measured though not very accurately, will be equal to the Angle AEB, and this Angle under which the Diameter of the great Orbit of the *Earth* is seen from the fixed *Star* E, is called *the Parallax of the great Orbit*. Now were there Instruments nice enough to measure this Angle with great certainty, as in Effect there are not; we could easily find the Distance of the *Star* E from the *Earth*; for we have in the Triangle ABE, the Angle EAB the visible Distance of the *Sun* from the *Pole*, the Angle of the *Parallax of the great Orbit* E, and AB the Diameter of the great Orbit given, and thence by *Trigonometry* AE or EB may be easily found. Now if we suppose the *Parallax of the great Orbit* with Mr. *Flamsteed* to be 42 Seconds, and

and if an Error be committed in Observation of 10 or 12 Seconds, and no Man can be sure he has not committed that Error; the Distance of the fixed *Star* thereby remains uncertain.

Of the Precession of the Equinoxes.

Having hitherto supposed the Parallelism of the *Earth's Axis* as immutable, and that the *Earth* had been affected with no other Motions, than it's annual one round the *Sun*, and its diurnal one round it's *Axis*. Yet *Astronomers* from many Years Observations have found, that the *Axis* of the *Earth* deviated about one Degree to the *West* in 72 Years from it's Parallelism, but that it still preserves its Inclination of $66\frac{1}{2}$ Degrees to the Plane of the *Ecliptic*; and though this slow Mutation of the *Earth's Axis* can by no Means disturb the *Phænomena* already explained in a few Years, yet in a *Century* or two it becomes very remarkable. Thus,

Fig. 84. Let the Line DCH represent a Portion of the *Earth's Orbit*; from the Center of the *Earth* C, let the Line CE be drawn perpendicular to the Plane of the *Ecliptic* meeting the concave Surface of the Heavens in E: This Line CE will be the *Axis* of the *Ecliptic*, and E the *Pole* of it. Let the *Axis* of the *Earth* Cp be continued to the Heavens; then P will be the *Pole* about which the Heavens will seem to revolve: Let a great Circle EPA pass through the *Poles* E and P and be continued to meet the *Ecliptic* in A, it will cut it perpendicularly, and the Arch PA will be the Measure of the Angle PCH; which is the Inclination

tion of the *Earths Axis* to the Plane of the *Ecliptic*, that is, it will be $66\frac{1}{2}$ Degrees, and therefore its Complement EP will be $23\frac{1}{2}$ Degrees, and will be the Measure of the Angle ECP, that the *Axes* of the *Ecliptic* and *Equator* make with each other. Let then the *Pole* P or Line CP be carried Circularly from *East* to *West* about the Center C, so as that it may constantly as it moves round, through PQFG, be inclined to the Plane of the *Ecliptic* in an Angle of $66\frac{1}{2}$ Degrees; by this Means the *Axis* PC describes the Convex Surface of a *Cone*, of which C is the *Vertex*, and the Point P the Circle of its Base, which Circle is not compleated in less than 25920 Years; after which Time, the Pole having left a *Star* at P, will again return to it; and this is truly the Nature of the Motion of the *Pole* backwards; for if it were not endued with this Motion, but that the *Axis* of the *Earth* retained the same Direction; the *Pole* of the Heavens would be found to be constantly in the Point P; but we find that *Pole* does as constantly change it's Place towards the *West*, so that in 72 Years it will proceed one Degree Westwardly from its Situation at P to Q, and BQ will be $66\frac{1}{2}$ Degrees, and thus by Degrees it will pass through every Part of the Circle PQFGP, making PA, QB, FC, CG, equally inclining to the Plane of the *Ecliptic* in an Angle of $66\frac{1}{2}$ Degrees. Hence in half the Period of the Polar Revolution, or whilst the *Pole* passes from P to G, a *Star* which had been at P will in 12960 Years be 47 or twice $23\frac{1}{2}$ Degrees distant from it.

Since

Since the *Earth's Axis* changes its Situation by moving backwards; this backward Motion must be communicated to the Whole, and occasion every Point on the *Earth's Surface*, also to move backwards or towards the West: The *Equinoctial* Points of the Earth, do therefore move continually backwards or towards the West, and thereby will occasion the Celestial Equinoctial Points with which they coincided, to proceed forward in *Consequentia*, or according to the Order of the *Signs* or fixed *Stars* towards the East, and this is called the *Precession* of the *Equinoxes*.

Hence it is that the Stars which compose Constellations have changed their Places since they were observed by the first *Astronomers*; thus, the Constellation of the Ram, which in the Time of *Hipparchus*, was nearly opposite to the Equinoctial Point *Aries* γ , is now removed a whole Sign towards the East, and is marked upon Celestial Globes to be in the Sign or Portion of the *Ecliptic*, *Taurus* δ ; in like manner, *Taurus* now resides in *Gemini* π , *Gemini* in *Cancer* ζ ; and so every Constellation has changed its Place since the first Observation: But though the Constellations or Images have left their Places, yet the twelve Portions of the *Ecliptic* which are called *Dodecatimoria* still retain the same Names, which they had in the Time of *Hipparchus*: And to distinguish them from *Starry Signs* or Constellations. they are called *Anastrous Signs*, or Signs without *Stars*.

The physical Cause for the Precession of the Equinoxes was unknown, untill Sir ISAAC NEWTON discovered that it arose from the oblate Spheriodical
Figure

Figure of the *Earth*; and that the Figure of the *Earth* arises from the Rotation of the *Earth* round it's Axis.

Though the Period of the *Earth's* annual Motion, is always performed in the same Time; yet the *Earth* in passing along its Orbit does not move uniformly; for if it did, the *Sun* would appear to move also uniformly; but the *Sun's* apparent Motion being irregular, the *Earth's* Motion must be so too; for he is found to be eight Days longer passing through the Northern Signs, than through the Southern ones, and therefore the Summer is eight Days longer than the Winter: And the *Sun's* apparent Diameter in Winter being greater than in Summer; it therefore follows, that the *Sun* must be farther from us in Summer than in Winter. In the Winter it is seen under an Angle of 32 Minutes 47 Seconds, and in Summer, under an Angle of 31 Minutes and 40 Seconds.

From hence it is plain, that the *Earth's* Orbit is not a Circle with the *Sun* in it's Center: And the great *Kepler* from the Observations of the industrious *Tycho Brahe* by unanswerable Reasons has shewn that the Orbit, of not only the *Earth*, but that of every Planet must be an *Ellipse* and not a Circle; and that the *Sun* is not in the Center of the Elliptical Orbit, but in one of the *Foci* or Points upon which it is described, as at S. Fig. 85. The longest Diameter or the *Axis* of the Ellipse AP is called the Line of the *Apsides*; the Point A is termed the higher *Apsis*, or *Aphelion*, being most distant from the *Sun*; and the nearest

F f Point.

Point P to the *Sun*, is called the lower *Apsis* or *Perihelion*: The Distance ES between the Center of the Ellipse and the Sun, is called the *Excentricity*: The Line ES drawn from the Extremity of the lesser Diameter to the *Sun*, is called the *mean Distance* of the *Planet* from the *Sun*; which is equal to half the *Axis*; it exceeding the shortest Distance by as much as the longest Distance exceeds it.

Though the Planetary Orbits are Elliptical, yet they differ but little from Circles; for the Excentricity of the *Earths* Orbit SC is only 17 of such parts, as the mean Distance SF is of 1000.

The *Planets* in revolving round their Orbits observe this immutable Law, that *they Describe equal Areas in equal Times*; and because their Orbits are Ellipses the Arches described in equal Times will be unequal, in order that the Areas may be equal. Thus, if in a given Time a *Planet* moves from A to B, and thereby produces the Area ASB; in order that it may produce the Areas BSD, PSF each equal to ASB, BD must be greater than AB, and FB greater than either, or the Areas will be unequal; and these Arches will be nearly reciprocal to their Distances from the Sun. This Law is demonstrated by the Sagacious *Kepler*, in his Commentaries on the Motion of the Planet *Mars*.

A *Planet* when at its *Aphelion* moves slowest; but it's Motion becomes quicker daily from thence to its *Perihelion*, where it is quickest
of

of all; and from thence again to its *Aphelion* it moves every Day slower.

Having shewn that the *Earth* is removed farther from the *Sun* in Summer than in Winter; it will be necessary here to shew and explain the Cause of the Summer Season, being warmer than the Winter one: First then, the Force of the *Sun's* Rays is much stronger when they fall directly, than when they fall obliquely; now in the Winter, the Rays fall very obliquely upon the Earth, and their Power is thereby diminished, for the Light being not so dense, the fewer must the Rays be in any given Space; and of course the more they must be spread and scattered, and consequently the Heat must be thereby lessened. Besides the *Sun* being much nearer the *Horizon* in the Winter than it is in the Summer, the Rays in the Winter pass through a much greater Quantity of Atmosphere than in the Summer, and are thereby more refracted and broke by the Reflections of so many Particles of Air; and this also is the Reason, that we can look at the *Sun* when it is in or near the *Horizon* without hurting our Eyes whereas when it rises higher, we cannot look at it without being almost blinded.

Again, the longer any hard and solid Body is exposed to the Fire, the hotter it grows. Now in the Summer we are heated by the *Sun*, about 16 Hours every Day, and have but 8 Hours of Night to cool, and in the Winter we are heated but 8 Hours, and cool 16; it therefore is plain, that there must be a great Difference of Heat and Cold in these two Seasons.

Since the Power or Heat of the *Sun* is greatest when its Rays fall upon us most directly or nearest to a Perpendicular, it should thence follow, that the Heat should be greatest when the *Sun* enters \odot *Cancer*, or about the 20 of *June*, for then it is nearest our Vertex, and lieth longest towards us; but we find it much warmer above a Month after, and warmest about the beginning of *August*, in the *Dog-Days*, though the *Sun* be removed above a whole Sign, from that Place, where he was most vertical.

Now to arrive at the true Cause of this Effect, it will be necessary to observe, that the Action of the *Sun's* Heat upon all Bodies, is not transient as it's Illumination, but permanent. So that a Body which is once heated, will retain that Heat for some Time after the *Sun* has left it, for the Particles of Heat being absorbed by the Body, cannot at once disengage themselves from it, but will continue in it for some Time before they can fly off, and loose their Force, or before the Body can cool; therefore if the heating Particles, which are daily received, exceed those which fly off in the Night, the Body must continually encrease in Heat. And this is our present Case, for the Particles of Heat do daily encrease for some Time after the *Sun* has entered \odot *Cancer*, since there are more entering into the *Earth*, in the Days than there are thrown off in the Night. Thus, let us suppose 100 Particles to be received in the Day, and 50 of these to be thrown off in the Night; there will then remain 50 to excite Heat: If then the next Day the *Sun* will impart 100 Particles,
of

of which one half of them are thrown off in the Night; in the beginning of the third Day, there will remain 100 Particles exciting Heat. In the same Manner, so long as there are more Particles of Heat emitted from the *Sun* upon the *Earth* in the Day, than can be dissipated or thrown off in the Night, the Heat must constantly encrease and become more intense: But when the Days decrease, and the Force of the *Sun's* Rays become weaker, there will be more Particles thrown off in the Night than there are received in the Day, and by that Means the Body will be heated less every Day, so that the Earth and Air at length will become extreamly cool.

Of the Moon's Phases and Motion.

The *Moon* as it was said before, is a secondary Planet which constantly attends the *Earth* in its annual Motion round the *Sun*, describing its Orbit in 27 Days and 7 Hours; it is the most splendid of all the heavenly Bodies except the *Sun*, and if viewed from the *Sun*, would never be seen above 10 Minutes distant from us.

The *Moon* puts on several Phases or Appearances, and is constantly changing its Figure, being sometimes Horned, then Half Full, afterwards Gibbous or Humped, then Full, again Gibbous, Half Full, and Horned: And these different Phases are easily accounted for, when we consider that she like the *Earth*, is an opaque spherical Body, which only shines by the Light she receives from the *Sun*, having always that half of her Body, which is next the *Sun*, enlightned while the rest remains involved

involved in Darknefs; but the half which is visible to us, is that which is opposite to the *Sun*, and therefore according to her various Situations with respect to the *Sun* and *Earth*, she will seem to undergo different Degrees of Illumination, having sometimes a greater, and at other Times a less Part of the enlightned Hemisphere turned towards the *Earth*, sometimes the whole, and at other Times no Part of her can be seen from the *Earth*. To explain which, *Fig. 86.* let S represent the *Sun*, T the *Earth*, RTS a Part of the *Earth's* Orbit, which it describes in its annual Motion round the *Sun* ABCDEFGH the Orbit of the *Moon*, in which it moves round the *Earth* from West to East, PNOM the *Moons* Body, and it's Center L. Let the Centers of the *Sun* and *Moon* be joined by the Right Lines SL, and let MLN be a Plane passing through the *Moons* Center perpendicular to the Line SL; then this Plane will cut the *Moon* in a great Circle, which will be the Boundary of Light and Darknefs, which seperates the enlightned from the obscure Side. In like Manner, if the Centers of the *Earth* and *Moon* be joined by the Line TL, which is perpendicular to the Plane PLO; that Plane will cut the *Moon* in a great Circle, called the *Circle of Vision*, which will seperate the Visible from the Invisible Hemisphere of the *Moon*.

Hence 'tis plain, that if the *Moon* be at the Point A of it's Orbit, that the Circle of Vision PLO, will coincide with the Circle MLN, which is the Boundary of Light and Darknefs, and so the enlightned Hemisphere of the *Moon* will be
turned

turned towards the *Earth*, and then with respect to us it is called *Full-Moon*; when therefore the *Moon* is full, it must consequently be in *Opposition* to the *Sun*, because from the *Earth*, the *Sun* and *Moon* then appear in opposite Parts of the Heavens, the one setting when the other rises. When the *Moon* comes to B, 'tis plain that the whole enlightned Disk or Hemisphere MPN, is not turned towards the *Earth*, there being a Part of it MP not to be seen by us; therefore the visible illuminated Part, will be deficient of being a Circle, and will be *Gibbous*. When the *Moon* arrives at C, where the Angle CTS is a Right Angle, the Angle TCS will differ very little from being also a Right Angle, upon Account of the vast Distance of the *Sun* from the *Earth* and *Moon*, so that CS and TS may be looked upon as parallel; therefore the Circle of Vision OP, will bisect the Boundary of Light and Darknes MN at Right Angles, and so half of the enlightned Hemisphere will only be visible to us, and then she is called an *Half-Moon*, and is said to be in a *Quadrant-Aspect*, or to be in one of her *Quadratures*, or within a Quadrants Distance of the *Sun*. When the *Moon* has got to D, then only a small Part PN of the enlightned Hemisphere, is turned towards the *Earth*; and therefore because the *Moon* is of a spherical Form, that visible enlightned Part, will appear horned, with the Horns turned to the *Westward*. When the *Moon* arrives at E, the Circle Bounding Light and Darknes, will coincide with the Circle of Vision, and then the *Moon* will disappear, having its darkned Hemisphere turned towards

towards the *Earth*; and when it is in this Situation it is said to be in *Conjunction* with the *Sun*, and to be *New-Moon*. When the *Moon* advances to F, she again assumes an horned Figure; but the Horns which before the *New-Moon* were turned to the *Westward*, are now turned to the *Eastward*. When the *Moon* arrives at G, she is again in a *Quadrant-Aspect*, or in one of her *Quadratures*, where she will be an *Half-Moon*, and at H she will be more than half full or *Gibbous*; but in A she will again appear with a *full Face*.

As the *Moon* enlightens the *Earth* by its reflected Light from the *Sun*; so the *Earth* enlightens the *Moon* by its reflex Light: And because the Surface of the *Earth* is above fifteen Times greater than that of the *Moon*, therefore the *Earth* may well be supposed to give the *Moon* a Light, which is fifteen Times greater than that it receives from it.

In *New-Moons* 'tis plain that the enlightned Hemisphere of the *Earth* is fully turned towards the *Moon*, and will therefore at that Time illuminate the dark Side of the *Moon*; and then the *Lunarians* will have a full *Earth*, as we in a similar Position have a *full Moon*. And hence it is that, a dim Light is observed in the old and new *Moons* whereby we see the rest of the *Moon's* Body, besides the bright Part which is horned. When the *Moon* is full, then the *Sun* and *Earth* will appear in *Conjunction* to it, and the *Lunarians* will then have a new *Earth*; after which the *Earth* will appear Horned to them. In short the *Earth* will shew
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the same Appearances to the Inhabitants of the *Moon*, as the *Moon* does to us.

Though as before, the *Moon* describes its Orbit in 27 Days and 7 Hours called a *Periodic Month*, yet the Time it takes from one Conjunction to the next, will be nearly 29 Days 12 Hours, which is called a *Synodic Month*. Thus, Fig. 87. let S represent the *Sun*: T the *Earth*, AB a Part of the *Earth's* Orbit round the *Sun*, and ALDC the Orbit of the *Moon*: Let the *Earth* be at T, and the *Moon* at L, in Conjunction with the *Sun*: Now while the *Moon* is moving from L round it's Orbit, it's plain that the *Earth* must make some Progress through it's Orbit, carrying the *Moon's* Orbit along with it: So that while the *Moon* has moved quite round it's Orbit, the *Earth* will be carried from T to t, and the *Moon's* Orbit will be in the Situation *l'a c d*, and the Point L will be in the Line *tl*, parallel to the former TL, and consequently the *Moon* will be then in *l*, and will have compleated it's *periodic Month*; but it will not be in Conjunction with the *Sun* 'till it has moved farther on to M, when it will have compleated it's *Synodic Month*.

If the *Moon's* Orbit lay in the Plane of the *Ecliptic*, that is, if the *Earth* and *Moon* moved in the same Plane; 'tis manifest that in about a Month, the *Moon* would be seen to describe the same Circle in the Heavens, that the *Sun* appears to do in a Year, that is, it would describe the *Ecliptic* Circle: But because the *Moon's* Orbit, does not lie in the same Plane with the *Earth's*, or in the Plane of the *Ecliptic*, but is inclined to it in an Angle of

about five Degrees; the *Moon* is seen to be sometimes above, sometimes below; and at other Times in the *Ecliptic*. Thus, *Fig. 88.* let AB be a Part of the *Earth's* Orbit, T the *Earth*, CEDF the Orbit of the *Moon*, CGDH a Circle of the same Diameter with that of the *Moon's* Orbit, lying in the Plane of the *Ecliptic*. These two Circles being in different Planes, and having the same Center T, will intersect each other in the Extremities of the Line DC, which passes through the *Earth*; and one half of the *Moon's* Orbit CED, will rise about five Degrees above the Plane of the Circle CGDH towards the *North*, while the other half DFC, will be as far below it towards the *South*. The Right Line DC at whose Extremities the two Circles intersect each other, is called the Line of the *Nodes*; and the Points D and C are called the *Nodes*. The *Node* C where the *Moon* begins to ascend Northward, is called the *ascending Node*, or the *Dragon's Head*, and is thus marked ♄; the other *Node* D whence the *Moon* begins to descend to the Southward, is called the *descending Node*, or the *Dragon's Tail*, and is thus marked ☊. Hence 'tis plain, that the *Moon* cannot appear to be in the *Ecliptic*, but twice in it's Period round the *Earth*, that is when it is in a *Node*; and that the more distant it is from a *Node*, it is the farther removed from the Plane of the *Ecliptic*: The two opposite Points of it's Orbit E and F that lie in the Middle between the *Nodes*, are called the *Limits*; because they shew the utmost Distance the *Moon* can be from the Plane of the *Ecliptic*.

It has been found from Observations, that the Line of the *Nodes* changes it's Situation from *East* to *West*, contrary to the Order of the Signs, and by this retrograde Motion, finishes it's Circulation in about 19 Years; after which Time the *Nodes* return to the same Points of the *Ecliptic* again.

*Of the Inequalities in the Moon's Motions,
and of it's Surface.*

Hitherto we have considered the *Moon* to move in a Circular Orbit about the *Earth*, but Observations have convinced us that she is sometimes nearer, and at other Times farther from us, and therefore that her Orbit is of an elliptic Form, in one of the *Foci*, of which *Fig. 89.* is the *Earth* T; the greater *Axis* of the Ellipse AP is called the Line of the *Apsides*, TC is the *Eccentricity*; the Point A or highest *Apsis* which is most distant from the *Earth* is called the *Apogee* of the *Moon*; and the lowest *Apsis* P, is called it's *Perigee*, being that Point of the *Moon's* Orbit, which is nearest to the *Earth*.

The *Moon's* Orbit is not only carried with the *Earth* round the *Sun*, but it has a Motion from *West* to *East* about the *Earth*, in the Space of almost nine Years, in which Time it will return to it's former Situation.

The periodical Months are not equal. For when the *Earth* is in it's *Aphelion*, or most distant from the *Sun*, the *Moon* being so likewise; she then moves quicker, and performs her Circulation

in less Time. Again, when the *Earth* is in it's *Perihelion*, or is least distant from the *Sun*, the *Moon* being so likewise; the *Moon* then moves slower and performs it's Circulation in a greater Time: Seeing therefore that the *Moon* revolves about the *Earth* in a less Time, when the *Earth* is in it's *Aphelion*, than when it is in it's *Perihelion*; the periodical Months cannot be equal.

When the *Moon* is in either of the *Syzygia* A or P, or in those Points of it's Orbit, which are in a Line with the *Sun* and *Earth*, she will then move swifter, than when she is in the *Quadratures*.

According as the *Moon* is removed from the *Syzygia* she slackens her Pace, and increases it as she goes towards either of them. Thus, from her Change to the first Quadrature, she every Day moves slower, and from that Quadrature to the Full, she moves quicker daily; again, from the Full to the last Quadrature, she every Day moves slower, and from the last Quadrature to the Change, she daily moves swifter. This Inequality is called the *Moon's Variation*, and was first discovered by *Tycho Brahe*.

The *Moon* moving in an Ellipse round the *Earth*, describes equal Areas in equal Times, as the primary *Planets* do in moving round the *Sun*; therefore the *Moon* must be quickest in the *Perigeon*, and slowest in the *Apogeon*.

The Orbit of the *Moon* is changeable, for it increases and decreases: It is greatest, for the *Excentricity* is greatest, when the Line of the *Apsides* coincides with the *Syzygia*, or when it is in the Line
that

that joins the *Sun* and *Earth*; and the Excentricity is least, when the Line of the *Apsides* is at Right Angles with the other. The Difference between the greatest and least Excentricity is so considerable, that it is half of the least.

The *Apogee* of the *Moon* is also variable, sometimes moving forwards, and again backwards. When it coincides with the *Syzygal* Line, it moves forwards, but when it cuts that Line at Right Angles, it moves backwards, and it's Progress and Regress are very unequal. When the *Moon* is in her Quadratures, the *Apogee* goes but slowly forwards, stands still, or moves backwards: But when the *Moon* is in Opposition to the *Sun*, the *Apogee* has a quick Motion forwards.

The Motion of the *Nodes* is also variable, for when the Line of the *Nodes* coincides with the *Syzygal* Line, they have no Motion; but when they cut that at Right Angles, they go swiftly backwards from *East* to *West*.

All these Irregularities were first discovered by Sir ISAAC NEWTON, who has shewn that they all arise from the *Theory of Gravitation* of Matter to Matter.

The only regular Motion the *Moon* is endued with, is, that in one single Rotation round her *Axis*, she moves round her Orbit; by which Means she always keeps the same Face to us: Yet this very Regularity is the Cause of a seeming Irregularity. If indeed the *Moon's* Orbit were a Circle, then we would always see the same Face: But because it is an Ellipse, in one of whose *Foci* is the *Earth*; we cannot see the very same Face,
by

by it's describing equal Areas in equal Times; but sometimes we see more of its *Eastern* Limb, and at other Times more of its *Western* Limb; and these Appearances are called the *Librations* of the *Moon*.

If the *Moon's* Disk or Face, were smooth as a convex Mirror, it would only reflect the *Sun's* Rays in certain Directions, which would terminate in a Point, where the *Sun's* Image would be seen very small, but with immense Lustre: It would not reflect Light as it does by diffusing it on all Sides, if it's Surface were not very rough and uneven.

That the Surface of the *Moon* is not only rough and uneven, but that there are many Hills and Vallies thereon, may be thus proved. If it's Surface were smooth, the Arch described by the Terminator of Light and Darknes, either in a horned, or a gibbous *Moon*, would appear to be a regular Curve, free from any Excrescences; and in the Quadratures, the Terminator of Light and Darknes, would be a Right Line. But by viewing the *Moon* through a Telescope, we find there are no such regular Curves or Lines to be seen on it's Disk, but that the Confines of them are tinged or illuminated with a Multitude of Spots and Breaks disorderly scattered. From the third to the fifth or even to the sixth Day of the *Moon*, there may be observed many shining Points scattered in the dark Part near the Light, which being observed through a Telescope, will in a few Minutes be found to dilate and expand themselves gradually, 'till they join the light Part; and in
the

the mean Time new Spots again are continually appearing at some Distance from the light Part, which again expand in a few Minutes and are joined to the Light, and the contrary is found in the last six Days of the *Moon*. Therefore the Surface of the *Moon* is not smooth but rough and uneven.

The Spots which appear without the illuminated Part, are the Tops of very high Mountains, which rise far above the other Parts of the Surface; and are therefore sooner illuminated than the lower Parts, and continue longest to shine. There are also in the illuminated Part of the *Moon* many dark Spots, which seem to be large Cavities, when the *Sun* shines obliquely upon them; but as the *Sun* rises more and more, the dark Parts become less and less, and at Length they vanish.

Astronomers find, that the Mountains in the *Moon* are much higher than those of the *Earth*. They have found some of them to be nine Miles high, which is three Times higher than the highest Hills on the *Earth*.

A Full *Moon* when viewed through a Telescope, is seen to abound with a great Number of large dark Spots, intermixed with white ones, which dark Spots are Cavities, and the white ones are Mountains. Some have imagined the dark Spots to be Seas, but they consist of a darker Matter than Water, which does not reflect the Light.

There are neither Clouds nor Vapours about the *Moon*, from whence Rain may be generated: If there were, they would sometimes cover it's Disk, or render some of its Parts obscure to us, which

which never happens. It is probable that the *Moon* has not even an Atmosphere, because the *Planets* and *Stars* which are seen near it's Limb, have not their Light refracted, as it is in passing through our Atmosphere. If any Atmosphere it has, it must be of a very extraordinary thin Nature. Hence there is a constant Series of fine serene Weather in the *Moon*.

Hevelius has given *Geographical* Names to the several Parts of the *Moon*, by calling some Islands, Countries, and Seas after those on the *Earth*, without any regard to Situation or Figure.

Of the Eclipses of the Sun and Moon.

All opaque Bodies, which are exposed to the *Sun*, cast a Shadow behind them, which Shadow is a privation of Light in the Space it possesses. The *Earth* therefore being an opaque Body, casts a Shadow into the Heavens in an opposite Direction to the *Sun*.

This being premised, we will shew that the *Sun* is bigger than the *Earth*. Thus,

1. *Fig. 80.* If the *Sun* and *Earth* were of equal Diameters, it is plain that, the Shadow of the *Earth* would form a Cylinder, which would be infinite.

2. *Fig. 81.* If the *Sun* were less than the *Earth*, it is also plain that, the Shadow would form an infinite truncated Cone, which being farther continued would take up still the greater Space. Now in either of these Cases, because the Shadows are infinite; sometimes the superior *Planets*, *Mars*, *Jupiter*, and *Saturn* would be involved in them,
and

and they would by that means suffer *Eclipses*. But these *Planets* have never been found to suffer *Eclipses*, therefore the *Sun* is neither equal to, nor is it less than the *Earth*, and consequently it must be greater than the *Earth*.

Fig. 82. Seeing therefore that the *Sun* is greater than the *Earth*, it is plain the *Earth's* Shadow must be in the form of a Cone, and must terminate in a Point. And because the *Moon's* Diameter is found to be contained about three Times in the Shadow, it is plain that the *Moon* must be less than the *Earth*.

Let S represent the *Sun*, E the *Earth*, and ABC *Fig 92* the conical Shadow. It is plain that there can be no Line drawn from the *Sun*, to any Point in the Space ABC which must not fall on the *Earth*; and seeing the *Earth* is an opaque Body, the *Sun's* Rays cannot pass through it, nor can they illuminate any Part of the Space ABC. Now when the *Moon* being opposite to the *Sun*, is involved in this Space, or Shadow, she suffers an *Eclipse* in the very Time of *Full Moon*.

The *Sun* being greater than the *Earth*, and the *Earth* again being greater than the *Moon*; the *Sun* must therefore be much greater than the *Moon*, and the *Moon's* Shadow must form a much less Cone than that of the *Earth*. Now if this Shadow of the *Moon* should happen to fall on the *Earth*, which can only happen when the *Moon* is in Conjunction with the *Sun*, then the Inhabitants of the *Earth*, on whom the Shadow falls, will be involved in Darknefs, and the *Sun* will seem to be in an *Eclipse*, so long as the Shadow covers

H h them

them. *Fig. 93.* But because it's Shadow is much less than the *Earth*, it can only cover a small Part of the *Earth*, such as BC; within which Space only a total Eclipse of the *Sun* will happen; because the Inhabitants in that Space, only are totally deprived of the Light of the *Sun*; whereas the circumjacent Inhabitants, who are near the Shadow, will see a Part of the *Sun*, and to such the *Eclipse* will be partial, and those who live about P, will see half the *Sun* eclipsed; But whoever lives between M and N, will at the same Time see the whole Body of the *Sun*, and will perceive no *Eclipse*.

Those Inhabitants who see a partial *Eclipse*, are said to be in the *Penumbra* of the Shadow, that is, they are neither in total Light nor Darkness; such as are in that Part of the *Penumbra*, which is nearest to the Shadow, cannot see as much of the *Sun's* Body, as those that are farther removed from it; therefore the former will see a greater *Eclipse* than the latter: and those who are without the *Penumbra*, will see no *Eclipse*.

If two Candles be placed a little distant from each other on a Table, and a Ball be placed on the Table about a Foot from them, in a Line which is at Right Angles to the Middle of a Line drawn, between the Centers of the Candlesticks; a conical Shadow of the Ball will be exhibited, and on either Side of it a *Penumbra*. In one Side of the *Penumbra*, the Candle on that Side only can be seen, and in that of the other Side, the other Candle can be only seen; But in the Shadow neither can be seen.

From

From what has been said 'tis plain, that there cannot be an *Eclipse* of the *Moon* but at a full *Moon*, or when the *Moon* is in opposition to the *Sun*; nor can there be an *Eclipse* of the *Sun*, or rather of the *Earth*, but at a new *Moon*, or when the *Moon* is in conjunction with the *Sun*. And Yet the *Sun* and *Moon*, do not suffer *Eclipses* every Month, which they would do if the *Moon's* Orbit were in the plane of the *Ecliptic*. But we have already shewn, that the *Moon* is never in the Plane of the *Ecliptic*, but when it is in a *Node*, or in one of those Points, where the Plane of the *Moon's* Orbit intersects the Plane of the *Ecliptic*; and therefore the *Sun*, *Moon* and *Earth* cannot be in the same Plane, and in the same Right Line, unless the *Moon* be in a *Node*, and that *Node* be at the same Time in a right Line, connecting the Centers of the *Sun* and *Earth*. When this happens, and the *Moon* be at the *Full*, the *Axis* of the *Earth's* Shadow will pass through the Center of the *Moon*; and then the *Moon* will suffer a total and central *Eclipse*. The Duration of an *Eclipse* therefore must be just as long as the *Moon* takes up in passing through the Shadow of the *Earth*, or through a Circle whose Diameter is three Times greater than the Diameter of the *Moon*, or so long as the *Moon* is passing through an Arch, which is equal to four of it's own Diameters, that is, about two Degrees; which Space, the *Moon* generally moves through in four Hours. Fig. 94. Thus, if MN represents the transverse Section of the *Earth's* Shadow, at the Distance of the *Moon*, CD a Part of the *Moon's* Orbit described in

the Time of *Full Moon*, BGA a right Line in the Plane of the *Ecliptic*; F will be the Position of the *Moons* Center, when she first touches the Shadow, E the position of the same when she leaves it; G will be the *Node*, and the Center of the *Moon* when the Axis of the Shadow passes through it, I the *Moon's* Center when the whole Body is first involved in the Shadow, and H the same, when the *Moon* begins to quit the Shadow.

Because the Diameter of the *Earth's* Shadow is much greater than the Diameter of the *Moon*; it is plain, there may be total, Eclipses of the *Moon*, when the *Moon* is not only in a *Node*, but when it is near one. For the *Node* may be at such a Distance from the *Axis* of the Shadow, that the *Moon* may suffer a total though not a Central *Eclipse*; as in Fig. 95. or it may suffer a Partial *Eclipse*, as in Fig. 96. 97. But when the *Node* is removed from the *Axis* of the Shadow above twelve Degrees at the Time of *Full Moon*; the *Moon* then will have so great a Latitude, or will be removed so far above, or beneath the Plane of the *Ecliptic* that it will pass over, or under the Shadow and will not be eclipsed. Therefore an Eclipse of the *Moon* can only happen at a *Full Moon*, and that only when the *Moon* is in a *Node*, or within twelve Degrees of one.

Just as the *Earth's* Shadow when cast upon the *Moon*, produces an *Eclipse* of the *Moon*; so likewise will the *Moon's* Shadow when cast upon the *Earth*, produce an *Eclipse* of the *Earth* in those Places where the Shadow falls, as was already shewn. But those *Eclipses* of the *Earth*, or as they
are

are more commonly, but improperly called *Eclipses* of the *Sun*, since the *Sun* never ceases to shine, cannot be total with respect to the *Earth*, that is, the *Moon's* Shadow cannot involve the whole *Earth* at once in Darkness, seeing as before the *Moon* itself is much less than the *Earth*; and again, the *Moon's* Shadow still less: So that to those Inhabitants which are in the *Axis* of the *Moon's* Shadow, the *Sun* can only be totally and centrally *Eclipsed*; to those who are in any Part of the Shadow that is not in the *Axis* of the Shadow, the *Eclipse* will be total; to those who are in the *Penumbra*, it will be partial; and those who are without the *Penumbra*, will see no *Eclipse*.

It sometimes happens, that there is a central *Eclipse* of the *Sun*, which is not total. This happens when the *Moon's* Shadow does not extend so far as the *Earth*, for to those Inhabitants of the *Earth* which are immediately under the Vertex or Top of the conical Shadow, the *Moon's* Center will appear to coincide with that of the *Sun*; and the *Moon* will not then obscure all the *Sun's* Disk, but will leave a lucid *Annulus* or Ring, between it's Verge, and that of the *Sun*. And such an *Eclipse* is called an *annular* one.

Of the Directions, Stations and Retrogradations of the Planets.

From what has been already said concerning *Venus*, it is Plain that she undergoes the same *Changes* and *Phases* that the *Moon* does, and no doubt *Mercury* also does.

These

These inferior Planets are seen more *Easterly* than the *Sun*; from the Time of their superior, to that of their inferior Conjunction; during which Time they set after him, and then they are *Evening Stars*. But from the Time of their inferior, to that of their superior Conjunction, they are seen *Westward* of the *Sun*; and consequently they set and rise before him, and then they are *Morning Stars*.

It is plain that these Planets are continually changing their Distances from the *Earth*, and that their Distances in their superior Conjunctions, must exceed those in their inferior Conjunctions by the Diameter of their respective Orbits. By this Means *Venus* appears six Times nearer us in her inferior, than in her superior Conjunction. but these greatest and least Distances are sometimes changed; because the Planets move in elliptical, and not in circular Orbits, as we have hitherto supposed. For *Venus* is most remote from the *Earth*, when the superior Conjunction happens at the very Time that both she and the Earth are in their Aphelions; and the Distance of *Venus* and the Earth is least, if the inferior Conjunction happens at a Time when *Venus* is in her Aphelion, and the Earth is in it's Perihelion.

It was before said that *Venus* was observed by Mr. *Horrax*, to appear like a Spot upon the Disk of the *Sun* in 1639, which is a Sight seldom to be seen. But the like may be again seen upon the 26th Day of *May*, 1761 in the Morning, if Clouds do not interpose.

The

The Lustre of *Venus* decreases in a duplicate Proportion as the Distance increases, therefore she will not appear as bright when she is full as when she is nearer the Earth; Dr. *Halley* has shewn that *Venus* is brightest when she is about 40 Degrees removed from the Sun, and that then no more than a fourth Part of her lucid Disk is to be seen. In this Situation *Venus* is often seen in the Day Time, and even when the Sun is shining.

This extraordinary Lustre of *Venus* is truly admirable, since the like is not to be found in any of the other Planets, nor even in the Moon. 'Tis true the Moon's Light is much the greatest as her apparent Magnitude abundantly exceeds that of *Venus*; yet it's Light is but dead and dull when compared with the sprightly brisk Light of *Venus*.

The Orbits of the Planets are inclined to the Plane of the Ecliptic in different Angles. Thus, the Orbit of *Saturn* is inclined to the Plane of the Ecliptic in an Angle of 2 Degrees and 30 Minutes; that of *Jupiter* in an Angle of 1 Degree 20 Minutes; that of *Mars* in an Angle of 1 Degree 52 Minutes; that of *Venus* in an Angle of 3 Degrees 24 Minutes; and that of *Mercury* in Angle of 6 Degrees 54 Minutes.

The Line where the Plane of a Planet intersects that of the Ecliptic, is called the *Line of the Nodes*, and the Extremities thereof are the *Nodes*. A Planet therefore can never be seen in the Ecliptic, but when it is in the Node. When a Planet is in any other Part of it's Orbit, it is either on the

North

North or South Side of the plane of the Ecliptic. This Deviation from the Plane of the Ecliptic, when viewed from the Earth is called the *Geocentric Latitude* of the Planet, but if viewed from the Sun it is called the *Heliocentric Latitude*. Now whenever a Planet comes to the same Point of it's Orbit, the Heliocentric Latitude will be the same, and it will be greatest, when the Planet is 90 Degrees from a Node. But the Geocentric Latitude will vary, because the Earth will be nearer to, or farther from a Planet at one Time than at another, when the Planet is in the same Point of it's Orbit.

If a Zone or broad Circle of 8 Degrees be conceived to be carried parallel to each Side of the Ecliptic; these two Zones compose one Zone, which is 16 Degrees broad; and this Space is called the *Zodiac*, within which the Planets always move.

The fixed Stars that are within the *Zodiac* are thrown into twelve *Constellations*, or *Asterisms*, viz.

1. ♈ Aries, the *Ram*. 2. ♉ Taurus, the *Bull*.
3. ♊ Gemini, the *Twins*. 4. ♋ Cancer, the *Crab*.
5. ♌ Leo, the *Lion*. 6. ♍ Virgo, the *Virgin*.
7. ♎ Libra, the *Ballance*. 8. ♏ Scorpio, the *Scorpion*.
9. ♐ Sagittarius, the *Archer*. 10. ♑ Capricornus, the *Goat*.
11. ♒ Aquarius, the *Waterer*. 12. ♓ Pisces, the *Fishes*.

The Planets *Mercury* and *Venus* move much swifter in their Orbits at one Time than at another; and their Motion at sometimes appears to be direct, or according to the Order the Signs of the

the

A TABLE OF THE DIMENSIONS, MOTIONS, &c. OF THE PLANETS.

	Saturn	Jupiter	Mars	Earth	Venus	Mercur.	Sun	Moon							
<i>Periods</i>	y 29 d 167	y 11 d 315	y 1 d 322 h 365 m 6 s 9	d 365 h 6 m 9	d 224 h 17	d 87 h 23	-----	d 27 h 7 m 43							
<i>Diurnal Revolutions</i>	Not known	9	56	24	40	23	56	23	0	Not known	25	6	27	7	43
<i>Me. dist. from. Sun. Mil.</i>	777000000	424000000	123000000	81000000	59000000	32000000	-----	-----							
<i>Diameters in Miles</i>	93450	130600	4875	7970	7906	4240	763000	2175							
<i>Proportion of Bulk</i>	161	4400	$\frac{1}{4}$	1	$\frac{39}{40}$	$\frac{1}{7}$	878000	$\frac{1}{50}$							
<i>Quantity of Matter</i>	126	827	Not	1	Not	-----	228700	$\frac{1}{40}$							
<i>Gravity on the Surface</i>	92	3.08	known	1	known	-----	24	34							
<i>Inclination of their Orbits</i>	2	30	1	52	0	0	5	24	6	54	-----	5	Variable		
<i>Inclination of their Axes</i>	-----	Very little	0	0	23	29	75	0	-----	8	0	3	10		
<i>Proport. of Light and heat</i>	$\frac{1}{100}$	$\frac{1}{28}$	$\frac{3}{7}$	1	$\frac{3}{4}$	$\frac{1}{2}$	4500	Variable							
<i>Velocities; Miles an Hour</i>	19000	25400	47240	58050	68040	62700	-----	2300							
<i>Place of ascending node</i>	Can. 22	Can. 8	Tau. 19	-----	Gem. 15	Ari. 15	-----	Variable							
<i>Place of the Aphelion</i>	Sag. 28	Lib. 9	Vir. 1	Cap. 8:25	Aqu. 5	Sag. 13	-----	Variable							
<i>Excentricities; Miles</i>	44320000	20440000	108112000	1368600	606400	6634000	-----	Variable							
<i>Mean Motion in the Eclip.</i>	0 2 0	0 4 59	0 31 27	0 59 8	1 36 8	4 5 22	-----	13 10 35							

Satel. of Saturn.	Periods round Saturn.	Distance from Saturn; Miles	Satel. of Jupiter.	Periods round Jupiter.	Dist. from Jupiter Mil.
	d h "			d h ' "	
1	1 21 19	2 0 2 8 0 0	1	1 18 28 36	363600
2	2 17 40	2 5 9 7 0 0	2	3 13 17 54	580000
3	4 12 27	3 6 2 9 0 0	3	7 3 59 36	925000
4	15 22 41	8 4 1 0 0 0	4	16 18 5 12	1630000
5	79 22 0	24 6 3 0 0 0			240000

From the Earth to the Moon

Calculated from the most accurate

Observations by the late

Mr. John Booth.

Place this opposite to Page 240.

THE HISTORY OF THE

REIGN OF

CHARLES THE FIRST

BY

JOHN BURNET

OF THE UNIVERSITY OF OXFORD

IN TWO VOLUMES

LONDON

Printed by J. Streater, at the Sign of the Gun, in St. Dunstons Church-yard

1679

By Authority

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1679

the Zodiac. Sometimes their Motion appears *Retrograde*, or in a contrary Order of the Signs, and sometimes they appear to be *Stationary*, or without any Motion at all, for some Days together. All which is occasioned by the Earth and these Planets moving in concentric Orbits, one within another, but with different Velocities.

Fig. 98. Let the lesser Circle about the Sun represent the Orbit of Mercury, and the larger the Orbit of the Earth. Now because the Earth moves through only one Quarter of it's Orbit, in about the same Time that *Mercury* makes one entire Revolution round us; or that one Quarter of the Earths Orbit which is run through in 12 Weeks, may answer or be equal to the Time of *Mercury's* Period; let us divide one Quarter of the Earths Orbit into 12 equal Parts, and the entire Orbit of Mercury into the like Number of equal Parts, as in the Scheme; then it is plain that when the Earth is at o in it's, and Mercury at o in his Orbit, he appears at o in the Zodiac. About a Week after, when the Earth is in 1 in it's and *Mercury* is at 1 in his Orbit, he will appear to be at 1 in the Zodiac. In the Like Manner when the Earth is at 2, 3, 4, 5 &c. in it's Orbit, and if at the same time *Mercury* be at 2, 3, 4, 5, &c. in his, Mercury will be seen to be in 2, 3, 4, 5, &c. in the Zodiac. So that from the Time the Earth leaves o, and Mercury leaves o, till the Time that the Earth arrives to 4 and Mercury to 4, the Planet appears to move *Direct*, and it's Motion becomes slower. About the Time the Earth is at 4, and Mercury is at 4 he will appear *Stationary*

nary; for though the Tangent Line 444 can touch the Orbit of *Mercury* but in one Point, yet a little before *Mercury* arrives at that Point, and a little after he has quitted it, he will be found to appear very nearly in one and the same Point. At 555 he appears to move *Retrograde*, also at 666 when he is in his Inferior Conjunction, and at 777 till about 888, he is again *Stationary*; after which at 999 and 10 10 10, he becomes again *Direct*; and more swiftly at 11 11 11 and 12 12 12. The Case of *Venus* is the same.

The Superior Planets *Mars*, *Jupiter*, and *Saturn*, are by Turns Morning and Evening Stars, as well as the inferior ones are; and they also appear *Direct*, *Stationary* and *Retrograde*.

Fig. 99. Let the lesser Circle about the Sun represent the Orbit of the Earth, and the larger that of *Jupiter*, who moves through, about a 12th Part of his Orbit, while the Earth compleats it's Revolution round the Sun. When the Earth is at o in it's, and *Jupiter* at o in his Orbit, he is seen at o in the Zodiac, about a Month after at 111 he appears *Direct*; and near his Conjunction with the Sun; at 222 and 333 he continues *Direct* though more slow in his Motion; about 444 he is *Stationary*; at 555 he appears *Retrograde*, as also at 666 when he is in Opposition, and at 777, till about 888; and then he is again *Stationary*; after which at 999 and 10 10 10, he becomes again *Direct*, and more swiftly at 11 11 11 and 12 12 12. The Case of *Saturn* and *Mars* are much the same.

Seeing the *superior Planets* appear *Direct*, *Stationary*, and *Retrograde*, the Earth must have it's
annual

annual Motion round the Sun; for if it had no such Motion, they could never appear otherwise than *Direct*.

Astrologers ascribe to the *Planets* a certain Influence they conceit they have upon us, according to their different *Aspects* *, and by which they pretend to foretell Events. But whoever considers the vast Distance they are from us, and the probability of their being habitable Worlds, will not easily be induced to believe so great an Absurdity.

Of Comets.

Comets, or Blazing-Stars were antiently supposed to be Meteors, or Exhalations, set on Fire in the Atmosphere; but the modern Astronomers have found that they are not only above the Earth's

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Atmos-

* *Aspects* of the heavenly Bodies, signify their Situation in the Zodiac, with respect to one another, of their Distance from one another in Longitude. The Name and Characters of the different *Aspects* are.

1. * *Sextile*, when they are two Signs, or 60 Degrees asunder.
2. □ *Quartile*, when they are three Signs, or 90 Degrees distant.
3. Δ *Trine*, when they are four Signs, or 120 Degrees from each other.
4. ♂ *Opposition*, when they are six Signs, or 180 Degrees asunder.
5. ☿ *Conjunction*, when they are in the same Sign and Degree.

Atmosphere, but that they are even beyond the Moon's Orbit. It is probable that they are very excentrical Planets, which move periodically round the Sun, or that their Orbits are very long *Ellipses*, having the Sun in one of their *Foci*.

The Motion of *Comets* is very variable, for some go from *West* to *East*, others from *East* to *West*; some from *North* to *South*, and again others from *South* to *North*; in short they move in all Directions, so that they have no Zodiac to contain them.

There have not been many more than twenty Planets, which have been hitherto observed, so as their Paths in the Heavens have been particularly traced and described; and the periodic Times of only two or three of them are yet known.

When the *Comets* descend near to the Sun, they become visible, and continue so for some Time, till they ascend again, and leave him; and as they remove by Degrees from the Sun, we loose Sight of them, and at length they disappear, and are not again seen for a long Time.

When a *Comet* descends near the Sun, it becomes greatly heated, and it's Tail seems to be a long and lucid Train of Vapours, which issue from the Body, in a contrary Direction to the Sun.

Comets are divided into three Kinds, viz. *Caudati*, or *Tailed*, *Barbati* or *Bearded*, and *Criniti* or *Hairy*. This Division does not arise from any real Difference there is in the *Comets* themselves,

but

but from different Circumstances of the same Comet. Thus,

When a *Comet* is moving toward the Sun, the Train of Vapours follows it, like a *Tail*.

When the *Comet* is moving from the Sun, or when it has left it's Perihelion, the luminous Vapour precedes or goes before it, in the Manner of a *Beard*.

When the Vapour is projected directly behind the *Comet* with respect to us, it is almost from our View ; for we then see only a little of it appearing round the *Comet*, like a Border of *Hair*. This Appearance is owing partly to the Expansion of the Train, which widens as it recedes from the Head of the *Comet*, by which Means we see some of the remote Vapours about it ; and partly, because what is raised by the Heat of the Sun, is thrown off by the Nature of Gravitation, the contrary Way. For as in the Atmosphere, the Smoke of all heated Bodies, ascends from the Earth towards which the Body gravitates ; so in the Heavens, where all Bodies gravitate towards the Sun, Smoke and Vapours must ascend from the Sun ; therefore the Vapours which are raised from that Side of the *Comet* which is towards the Sun, is turned backwards, and thrown the contrary Way. Consequently when the *Comet* is opposite to the Sun, and the heated Side is turned towards us on the Earth, the Vapours which must be in an opposite Direction to us, in returning back, are seen round the Edge of the *Comets* Disk ; which occasions us to compare it to *Hair*, because it bears some Resemblance thereto.

The

The *Tail* or *Beards* of a *Comet* appear longer or shorter, not only as it is projected to a greater or less Distance from it, but because it appears to us under a greater or lesser Angle. When the Tail is seen at a right Angle, it then appears longest, after which, as the Angle under which it is seen, becomes more and more acute, it will appear still to be the shorter.

Sir ISAAC NEWTON has computed, that the great *Comet*, which appeared in 1680 and in 1681, was on account of it's unusual proximity to the Sun, heated to so extraordinary a Degree, that it was 2000 Times hotter than red hot Iron. This *Comet* goes at least 11200 Millions of Miles from the Sun, and yet it does not arrive within a 40th Part of the Distance to the fixed *Stars*.

Bodies that are capable of bearing so intense a Heat, without being entirely dissipated and destroyed, must needs be very hard and solid; such therefore no doubt the *Comets* are.

Hevelius, found the Diameter of the *Comet* that appeared in 1665, to be three Times greater than the Earth's Diameter; and consequently it's Solidity, to be 27 Times greater than the Earth's. Spheres being to one another, as the Cubes of their Diameters.

The *Comet* that appeared in 1682, is supposed to be the same that appeared in 1607, and before in 1531; therefore it's Period must be 75 or 76 Years, and its Return may be expected in 1758. It's greatest Distance from the Sun, is to it's least, as 60 to 1; and it's greatest Light and Heat, is to it's least, as 3600 to 1.

The

The *Comet* that appeared in 1661, is supposed to be the same that appeared in 1532: and consequently it's Period is about 126 Years, and it's Return may be expected in 1789. It's greatest Distance is to it's least, as 100 to 1; and it's greatest Light and Heat is to it's least as 10,000 to 1.

The great *Comet* that appeared in 1680 and in 1681 is supposed to be the same that appeared in the 44th Year of the Christian *Æra*, and again in the Year of our Lord 531 or 532, again in 1106, and lastly in 1680; therefore it's Period must be 576 Years, and it's Return may be expected in the Year 2256. It's greatest Distance is to it's least, as 20,000 is to 1, and it's greatest Light and Heat is to it's least as 400,000,000 to 1.

We know little or nothing of the *Use of Comets*. They seem to be very unfit for the Habitation of Animals, because of their intense Heat, when they are near the Sun, and of their extream Cold, when they are farthest from it; yet we have no room to doubt, but they are made for much nobler Purposes, than to presage approaching Calamities; which several are idle enough to imagine they do.

Of the Tides.

The whole Globe of the Earth is every where pressed by Gravitation towards it's Center.

If the Surface of the Globe of the Earth were covered with a Fluid, and if some Parts of it's Surface were more pressed than others, the Parts which were most pressed, would be lowest, or nearest to the Center; and those that were least pressed, would be highest or most distant from the Center.

The

The Sun and Moon attract and are attracted by the Earth, and the Force of their Attraction pervades the whole Globe. But the Moon's Attraction is stronger than that of the Sun, because she is much nearer to the Earth than the Sun is.

The Effects of the Moon's Attraction upon the Fluids of the Earth, to alter their natural spherical Form, must be as follow.

The Middle Point of that Hemisphere of the Earth, which is next to the Moon, being more attracted by the Moon than any other Part of that Hemisphere, will by that Means be least pressed upon by it's own central Gravitation; and therefore the Waters will rise highest in that Point. The Point which is diametrically opposite to the aforesaid Point in the other Hemisphere, or that Point of the Earth, which is farthest from the Moon, being less attracted by the Moon than all it's other Parts, will therefore be left behind them; from whence it will follow, that the Surface of the Water at the Middle of that Hemisphere will be higher, or more remote from the Center, than in any other Part. These two middle Points will therefore be highest in their respective Hemispheres; the one being really *more elevated*, and the other being *less depressed* by the Moon's Attraction, than the adjacent Parts, and consequently the Earth may be looked upon to be of a spheroidal or oval Figure, whose longest Axis if produced, would pass through the Moon. Now by the Earth's Rotation, these highest Points will be continually shifting their Surface; from whence there will follow two *Flood Tides* and two *Ebb Tides* in

in the Space of 25 Hours; in which Time the Moon removes from the Meridian of any Place, to the same Meridian again.

When the Sun and Moon are in Conjunction with, or in Opposition to each other, that is at New or Full Moon; the Attraction of these two Bodies, acting upon the Earth in the same Right Line, their Force becomes united and so raises the Waters. And thus *Spring Tides* are produced.

When the Moon is in her Quadratures, her Attraction acts in one Direction, and the Sun in a quite contrary one; by this Means they correct or counteract one another, the Moon raising the Waters, where the Sun depresses them, and the Sun raising the Waters where the Moon depresses them. And thus Neap-Tides are produced.

It is plain, that if the two Protuberances, or Summits of Water, were always exactly at the Poles of the Earth, there would be no rising and falling of Waters, by means of the Earths Rotation, or no Tides at all; for it would constantly be high Water at the Poles, and low Water all round the Equator. And were the two Summits of Waters upon the Equator, or at their greatest Distance from the Poles; the Rise and Fall of the Waters, by means of the Earths Rotation, would then be greatest: Therefore the nearer these Summits are to the Poles, the Rise and Fall of the Waters are less, than when they are nearer the Equator. Consequently when the Sun and Moon are in Conjunction or Opposition, in or near the Equinoctial, as in *March* or *September*, the *Spring Tides* must rise

higher, the Summits being then upon the Equator, than when they are in Conjunction or Opposition in the Tropics as in *June* and *December*. And the Moon being in the Tropics at her Quadratures in *March* and *September*, and in the Equinoctial at her Quadratures in *June* and *December*, the *Neap Tides* will be less vigorous in the former Months, than in the latter. And besides when the Moon is in the Tropics at her Quadratures the Sun is in the Equinoctial; therefore the Rise and Fall of the Waters by his Influence, counteracting that of the Moon, is then greatest, though still less than that of the Moon; and consequently the *Neap Tides* and will then be weakest. But when the Moon is in the Equinoctial at her Quadratures, the Sun is in the Tropic, whose Influence in counteracting the Moon, is then least; therefore the *Neap-Tides* will then be strongest. so that the Difference between the *Spring* and the *Neap-Tides* is much less considerable at the *Solstitial*, than at the *Equinoctial* Seasons.

Yet the highest Tides of the Year are observed to be sometime before the Vernal, and sometime after the autumnal Equinox, viz. in *February* and *October*; which is owing to the Sun's being nearer the Earth in the Winter Months, when consequently the Force of his Attraction on the Waters, is greater, than in the Summer Months.

It has also been observed, that in this Part of the World, the Tides rise higher when the Moon is in the Northern Signs, at the Time of her coming to the Meridian above our Horizon, and when she is in the Southern Signs at the Time of her
com-

coming to the Meridian below the Horizon, than when she is in the Southern Signs above our Horizon, and in the Northern Signs below it. The Reason of which will evidently appear upon the Globe, *viz.* That in the former Cases, the Moon is nearer to our Zenith and Nadir, when she is upon our Meridian, or at the Time of high Water, and consequently we are then nearer to the Summits of Water, than in the two latter Cases. Though the Force, by which the Tides are raised is continually increasing, from the Time of the Moon's Quadrature to her Conjunction or Opposition, after which it gradually decreases untill the next Quadrature; yet the highest Spring-Tide is not just at the New or Full-Moon, but a Day or two after; which is thus accounted for.

If we conceive every Tide to be raised by a double Force, *viz.* Some Part of the Force by which the last Tide was raised still remaining, and the Force of a new Impulse. When both these together amount to more than the whole Force, which raised the last Tide, the present Tide must rise higher than the last did. Suppose the remaining Force to be always half the whole Force of the last Tide, and that the new Impulse, just at New or Full-Moon be 15, and the whole Force with which that Tide is raised be 22,

Let the new Impulse of the next Tide be but 14; then 14 and 11, (half of 22) will be equal to 25: This Tide will therefore be higher than the last. Let the new Impulse of the next Tide be but 13; then 13 and $12\frac{1}{2}$, (half of 25) will

be equal to $25\frac{1}{2}$. Consequently this Tide will rise still higher than the last did; though the Force of the Action of the two Luminaries, by which the Tides are raised, is now considerably abated.

For the same Reason, the deadeft or loweft Neap-Tides will fall out, not prefciſely at the Moon's Quarters, but ſometime after.



CHAP.

C H A P. X.

T H E

D O C T R I N E,

A N D

U S E *of the* G L O B E S.

A GLOBE or Sphere is a round Body, whose Surface is every where equally distant from it's Center. It may be conceived to be formed by the Rotation of a Semi-circle about it's Diameter.

The two Globes of which we here mean to treat, are artificial spherical Bodies: The one is called the *Terrestrial* or the *Terraqueous* Globe; because it's Surface comprehends a just Representation of the Globe of the Earth as it consists of Land, and Water: And the other upon which the *Starry Firmament* is described, is called the *Celestial Globe*.

We will therefore proceed to give a Description of such Things as are common to both Globes, and of those which are peculiar to the Terrestrial Globe, and so to it's Use; and then, after shewing the Parts which are peculiar to the Celestial Globe, we will proceed to shew it's Use.

There

There are Things as well without, as upon the Surface of each Globe, which are common to both Globes, *viz.*

1. The two *Poles*, are the Ends of the Spindle or *Axis*, upon which the artificial Globe turns; or they are the Ends of the imaginary *Axis* of the Earth. One of these is called the *North*, or the *Artic Pole*, from two *Bears* that are near it; and the other the *South*, or the *Antartic Pole*, being opposite to the former*.

2. The large graduated Brass Circle, which circumscribes the Globe, and which passes through the Poles is called the *Brazen Meridian*. It divides the Globe, into two equal Parts called the Eastern and Western *Hemispheres*, and it is divided into four Quadrants of 90 Degrees each, two of which are numbered from it's Middle to each Pole, and the other two are numbered from each Pole till they meet in it's Middle. The graduated Edge of this Meridian represents the Meridian of any Place, when, by turning the Globe, the Place is brought just under it.

3. The

* It will be here necessary to observe, that the Circles which are either about or upon the Surface of the Globe are distinguished into *Greater* and *Lesser*: the *greater* Circles divide the Globe into two equal Parts called *Hemispheres*, and the *lesser* Circles divide the Globe into two unequal Parts: Also, that every Circle whether great or small, is, or at least is supposed to be divided into 360 equal Parts called Degrees, and every of these into 60 equal Parts called Minutes: But a Degree in a great Circle, will be in the same Proportion to one, in a small Circle, just as the Circumference of one Circle is to the other; a Semi-circle therefore contains 180 Degrees, and a Quadrant 90 Degrees.

3. The *Rational Horizon* is the upper Edge of the wooden Circle; in which the Globe stands; it divides the Globe into an upper and a lower Hemisphere: It is so called to distinguish it from the *Sensible Horizon*, which limits our Prospect quite round us.

When the Sun or a Star gets above the Rational Horizon, it is then said to rise; and when they sink beneath it, they are then said to set. Now though the rational and sensible Horizons differ by the Semidiameter of the Earth, yet because the Heavenly Bodies are of a vast Distance from us, they may be considered as one and the same. For the whole Earth is but as a Point in comparison of the Sun.

Upon the upper Surface of the wooden Frame or Horizon are exhibited. (Counting from the out Side.) 1. The 32 *Rumbs* or Points of the Mariners Compass, of which the *East, West, North, and South* are called the *Cardinal Points*, dividing the Horizon into four equal Parts; and Lines drawn from any Point upon the Surface of the Globe towards the several Rumbs, are called *Rumb-Lines*.

2. The Days of every Month according to the Gregorian Account.

3. The like according to the Julian Account, and 4. The twelve Signs of the Zodiac are next distinguished by their Names, Characters, and Symbols; each Sign being divided into 30 Degrees.

4. The *Quadrant of Altitude* is a narrow thin Plate of pliable Brass, whose Edge is divided into

90 Degrees, and is exactly equal to one fourth Part of the Brazen Meridian. To the Top or upper Part or *Zenith* of this Meridian, it is screwed when it is used; which Part is every where 90 Degrees distant from the Horizon.

5 The *Horary Circle* is a small Circle of Brass, which is divided into twice 12 Hours: It is so fixed to the Brazen Meridian, that the Pole carries round the Hand which shews the Hour, and is the Center of the Circle: The Hours upon the East or graduated Side of the Meridian, are the Morning Hours, and these on the West Side are the Evening Hours.

6. A *Mariner's Compass* is sometimes placed on the Pedestal or Frame, in order that the North, South, East and West Points on the wooden Horizon, may point to those Parts of the Heavens.

7. The *Semicircle of Position* is a narrow thin Plate of pliable Brass, divided into 180 Degrees, and is exactly equal to half the Brazen Meridian, or it may be termed a double Quadrant of Altitude. It's Extremities are fixed to the North and South, so that it may be moved freely from the Horizon to the Meridian to any Position.

These Things we have described are without the Surface of each Globe. But on the Surfaces are the following Particulars delineated.

1. The *Equator* or *Equinoctial* Circle, or as Sailors term it, *the Line*, is that great Circle which lies in the Middle between the Poles. From this Line the Degrees of Latitude are counted towards each Pole. It divides the Globe into the Northern
and

and Southern Hemispheres, and it is divided into 360 Degrees from γ .

2 The Semicircles which extend from Pole to Pole, and cut the Equator at Right Angles are called *Meridians*. If 360 such Semicircles were drawn at equal Distances quite round the Globe, they would mark out the Degrees, which are numbered upon the Equator, and are counted from the first Meridian that usually passes through γ .

The *Ecliptic* is a great Circle that cuts the Equator obliquely in the two opposite Points γ and π , making with it an Angle of $23\frac{1}{2}$ Degrees; it is divided into 12 Signs each of 30 Degrees, in all 360. These 12 Portions are called by 12 different Names, *viz.*

1. γ Aries, the *Ram*. 2. τ Taurus, the *Bull*. 3. π Gemini, the *Twins*. 4. ϕ Cancer, the *Crab*. 5. Ω Leo, the *Lion*. 6. ν Virgo, the *Virgin*. 7. ζ Libra, the *Ballance*, 8. μ Scorpio the *Scorpion*. 9. δ Sagittarius, the *Archer*. 10. \wp Capricornus, the *Goat*. 11. \beth Aquarius, the *Waterer*. 12. \times Pisces, the *Fishes*.

On the Noon of every Day the Sun is on the Ecliptic, and passes quite through it in a Year; therefore if the respective Places of the Sun every Day at Noon, were united by Lines, the Whole would form the Ecliptic.

The apparent Motion of the Sun through the Ecliptic in a Year, is to be thus understood. If at Noon one Day the Sun be in a certain Sign and

Degree of the Ecliptic; he from that Time till the Noon of the next Day, moves nearly parallel to the Equator, and then is found to have advanced about a Degree farther in the Ecliptic: When he quits this, he moves on nearly parallel to the Equator, and by the Noon of the next Day he is found still to advance in the Ecliptic about a Degree farther, and so on every Day; constantly moving nearly but never exactly Parallel to the Equator; like a Screw that rises or falls as it's Circumference is carried round.

4 The *Lesser Circles* are the Tropics, and the *Polar Circles*. The two *Tropics* are each $23\frac{1}{2}$ Degrees distant on either Side of the Equator, and are parallel thereto. That on the North Side is called *the Tropic of Cancer*, to which the Sun is vertical at the Summer Solstice, and passes through the Sign ☉ *Cancer*. That on the South Side is called *the Tropic of Capricorn*, to which the Sun is vertical in our Winter Solstice, and passes through the Sign ♑ *Capricornus*.

5. The two *Polar Circles* are parallel to the Tropics, each at $23\frac{1}{2}$ Distance from it's Pole. The Northern Polar Circle is called the *Arctic Circle*, and the Southern one, the *Antartic Circle*.

The Parts we have thus far described are common to both Globes, and the following are peculiar to the Terrestrial Globe only.

1. The Degrees upon the Brazen Meridian, which are numbered from the Equator 0, 10, 20, 30, &c. to 90 or to each Pole, are of use to determine the *Latitude of any Place*, or it's nearest Distance from the Equator. And the Degrees
which

which are numbered from each Pole 0, 10, 20, 30, &c. to 90 or to the Equator, are of use to elevate the Pole to any Degree of Latitude. Hence it is plain that those who live under the Equator only, have no Latitude. Those that are nearest to it have their Latitude less than those that are farther off; and that no Place can have its Latitude more than 90 Degrees, as the Latitude of the Poles themselves are but 90.

2. The 360 Degrees upon the Equator, which are usually numbered from the Meridian which passes through *v*, and which is thence called the *Primary or the first Meridian*, are of use to determine the *Longitude of any Place*, or how many Degrees of the Equator, the Meridian of any Place is removed from the Primary Meridian. But this is the *old Method* of counting the Longitude.

The *new Method* is, to draw a Meridian through the Metropolis of the Kingdom, wherein the Globes are made; and from the Point where this intersects the Equator, the Equator is to be divided on either Side, or to the East and West, to 180 Degrees, 'till the two 180's meet. On *Senex's* Globes, the Longitude is expressed according to the old Method, and it is also set out from a Meridian which passes through *London*, according to the new Method.

Hence 'tis plain, that all places which are under the Meridian from whence Longitude is reckoned, have no Longitude. That according to the old Way of counting, the Longitude is numbered with the Sun and never exceeds 360 Degrees.

That according to the new Way, if the Primary Meridian be set under the graduated Edge of the Brazen Meridian, that the Globe is then divided into two Hemispheres, termed the Eastern and Western ones; in which Case the Longitudes of all Places are to be considered to be East or West, as they lie on the one or on the other Side of this Meridian, and that the greatest Longitude cannot exceed 180 Degrees.

If 360 the Degrees which go quite round the Equator, be divided by 24, the Hours in a Day and a Night, the Quotient 15 will shew, that the 24 Meridians called also *Hour Circles* which are usually drawn on Globes, are to be at 15 Degrees asunder; because the Places through which each of them pass, have Noon an Hour earlier than at 15 Degrees more Westward, and later at 15 Degrees more Eastward; and these 24 Meridians exactly correspond with the 24 Hours on the Horary Circle.

Hence it is plain, that if we have the Longitudes of two places given, we may tell how much sooner, or later, the one has the Sun upon it's Meridian than the other. Or if we have the Longitude of one Place and the Difference of Time between that and another Place, which is the *Difference of Longitude*, we may know the Longitude of the last Place.

3. *Parallelsof Latitude* are all Circles on the Globe which run parallel to the Equator.

Because the Meridians are widest asunder at the Equinoctial, and that their Distance diminishes the more, as the Parallel is nearer to the Pole; it therefore

fore follows a Degree or any Number of Degrees of the Equator, must be less than a Degree or any like Number of Degrees in any parallel.

Of the Divisions of the Earth.

The Surface of the Terrestrial Globe admits of several Divisions.

1. It is divided into five *Zones*, or Belts, which encompass it; and they bear their Names from their different Degrees of Heat. *viz.* One *Torrid Zone*, two *Temperate Zones*, and two *Frigid Zones*.

The *Torrid Zone* is contained between the two Tropics.

The *Temperate Zones* are contained between the Tropics and the Polar Circles, and the *Frigid Zones* are contained within the Polar Circles.

2. The Earth is divided into several Parts by *Climates*.

Climates are contained between Parallels of Latitude, drawn at such a Distance from each other as that the longest Day at the lesser Parallel, may exceed that at the next greatest Parallel by half an Hour.

There are 24 *Climates* between the Equator and each Polar Circle, which become narrower as they approach the poles. And there are six other *Climates* from each Polar Circle to it's Pole, which exceed one another by a Month.

A TABLE of the CLIMATES.

Climates	From the Equator to the Polar Circles.		Climates	From the Equator to the Polar Circles.	
	<i>Ends in</i>	<i>Where</i>		<i>Ends in</i>	<i>Where</i>
	<i>Latitud.</i>	<i>the long-</i>		<i>Latitud.</i>	<i>the long-</i>
		<i>est D. is.</i>			<i>est D. is.</i>
	D. M.	D. M.		M. D.	D. M.
1	08.25	12.30	17	64.06	20.30
2	16.25	13.00	18	64.49	21.00
3	23.50	13.30	19	65.21	21.30
4	30.20	14.00	20	65.47	22.00
5	36.28	14.30	21	66.06	22.30
6	41.22	15.00	22	66.20	23.00
7	45.29	15.30	23	66.28	23.30
8	49.01	16.00	24	66.31	24.00
9	51.58	16.30	From the Polar Circles to the Poles.		
10	54.27	17.00	1	67.30	1
11	56.37	17.30	2	69.30	2
12	58.29	18.00	3	73.20	3
13	59.58	18.30	4	78.20	4
14	61.18	19.00	5	84.00	5
15	62.25	19.30	6	90.00	6
16	63.22	20.00	Months.		

3 With respect to the Horizon ; some have the Poles in the Horizon, others have their Poles in the Zenith and Nadir ; and again others have their Poles between the Horizon and the Zenith and Nadir.

Such

Such as have their Poles in the Horizon, are said to be in a *Right Sphere*, because the Equator and all the Parallels are perpendicular to the Horizon, or cut it at Right Angles. The Inhabitants under the Equator are those to whom this Sphere or Position of the Globe, is only peculiar, where the Sun and Stars always rise and set perpendicularly, and where they have equal Day and Night throughout the whole Year.

Such as have their Poles in the Zenith and Nadir, are said to be in a *Parallel Sphere*, because the Equator and all the Parallels are then parallel to the Horizon. The Inhabitants (if any) who are under the Poles, this Sphere is only peculiar to; where they have but one Day and one Night in a Year.

Such as have their Poles obliquely situated, or whose Poles lie between the Horizon and the Zenith and Nadir, are said to be in an *Oblique Sphere*, because the Equator and the Parallels cut the Horizon obliquely. The Inhabitants of this Sphere are they who live on all Parts of the Earth, except under the Equator, or Poles; and their Pole must necessarily be elevated as much above the Horizon, as is the Latitude of the Place, in order that the Place may be in the Zenith, and that it's Inhabitants may have the Horizon quite round them; as the Inhabitants at every Place on the Earth have.

4. The Inhabitants of the Earth are divided with respect of one another into *Antæci*, *Periæci*, and *Antipodes*.

Those

Those who live on contrary Sides of the Equator, having their Latitudes equal, and who are under the same Meridian, or who have the same Degree of Longitude are called *Antæci*. The Hour is constantly the same in both, but the Seasons of the Year are contrary.

Those who are in the same Latitude, but in opposite Meridians or whose Longitudes differ 180 Degrees, are called *Periæci*. Their Seasons of the Year are the same, but their Days and Nights are contrary.

Those who live in opposite Parallels and Meridians are called *Antipodes*. Their Days, Nights, and Seasons, are all contrary to one another.

5. The *Natural Division* of the Earth, is that which Nature has made by Land and Water; The Land being divided into *Continents*, *Islands*, *Peninsulas*, *Isthmus's*, *Promontories*, *Mountains*, &c. and the Water is distinguished into *Oceans*, *Seas*, *Gulphs*, *Straits*, *Lakes*, *Rivers*, &c.

A *Continent* is a large Tract of Land containing several Countries, Kingdoms, and States, without having any of it's Parts seperated by Water.

An *Island* is a Tract of Land every where surrounded with Water.

A *Peninsula* is a Tract of Land which extends itself into the Sea, and is every where surrounded with Water, but in a narrow Neck, which joins it to the Continent. And that narrow Neck is called an *Isthmus*.

A *Promontory* is a *Cape* or *Head-Land* which shoots it self into the Sea.

A *Moun-*

A *Mountain* is a high rising Ground or Eminence, which overlooks the adjacent Country.

The *Ocean* is properly that general Collection of Water, which washes the several Parts of the Land and Continent.

A *Sea* is a Part of the Ocean interrupted by divers Islands, and nearly environed with Land.

A *Gulph* is nearly the same Portion of the Sea, as a *Peninsula* is of Land.

A *Strait* called sometimes a *Channel*, is an open narrow Passage between any two Shores.

A *Lake* is a Collection of Waters surrounded with Land, which has no visible Communication with the Sea.

A *Creek* is a narrow Part, or Arm of the Sea running a little Way into the Land.

A *Bay* is a much larger Inlet, and more safe and capacious for Ships to Anchor in.

A *River* is a considerable Stream of fresh Water issuing from one or many Fountains, which uniting with what trickles from the Sides of Hills, forms it self into one or more Channels through which it passes, till it is discharged into the Sea.

There is another Division of the Earth called the *Political Division* which is made by Men, who have distinguished it into four Parts or *Quarters*; and those again into *Empires, Kingdoms, States, Republics, Principalities, Provinces, Parishes, &c.* for a particular Description of which we refer to Mr. Gordon's, or to Mr. Salmon's Geographical Grammers, or to larger Systems.

The Use of the
Terrestrial GLOBE.

PROBLEM I.

To find the Latitude and Longitude of any given Place upon the Globe.

BRING the given Place to the graduated Edge of the Brazen Meridian; then the Degree of the Meridian that is over the given Place, will shew it's Latitude; and the Degree of the Equator which is at that Time under the Meridian, will be the Longitude of the Place.

PROB. II.

The Latitude and Longitude of a Place given, to find that Place upon the Globe.

Bring the given Longitude to the Brazen Meridian, and holding the Globe steady, find the given Degree of Latitude upon the Meridian; and the Place which lies under it, is that required.

PROB. III.

The Latitude of a Place being given, to find all Places on the Globe that are in the same Latitude.

With

With a Chalk, mark the Degree of Latitude upon the Brazen Meridian; and turning the Globe quite round, observe what Places pass under the Chalk; for those are they which have the same Latitude with the given Place.

P R O B. IV.

To find the Distance between any two Places on the Globe.

Lay the Quadrant of Altitude on both Places; or take their Distance with a pair of Compasses and apply it to the Equator. The Number of Degrees between them counted on the Quadrant, or that is between the Feet of the Compasses on the Equator, will be the required Distance in Degrees, which multiplied by 70, the Miles in a Degree, shews their Distance in Miles.

P R O B. V.

To find the Antæci, Periæci, and Antipodes, of any given Place on the Globe.

Bring the given Place to the Brazen Meridian; and having found it's Latitude, count the same Latitude on the Meridian towards the contrary Pole, and the Place under that Latitude will be that of the *Antæci*.

Keep the given Place to the Brazen Meridian, and set the Hour Index at the upper 12 or at Noon; and marking with Chalk the Latitude on

the Meridian, turn the Globe about, till the Hour Index points to 12 at Night; then the Place under the chalked Mark, will be that of the *Periæci*.

Keep the Globe now stayered, and count the same Latitude or that at the Chalk, to the contrary Pole; the Place under that Latitude, will be that of the *Antipodes*.

P R O B. VI.

A Place and the Hour being given at that Place; to find those Places of the Globe, where it is then either Noon, or Midnight.

Bring the Place to the graduated Side of the Brazen Meridian; fix the Hour Index to the given Hour, and turn the Globe about till the Index points at the upper 12, or to 12 at Noon: Then all those Places which are under that Semicircle of the Meridian to which the Index points, have the Sun in their Meridian, or have their Noon at that particular Time; and those who are under the opposite Semicircle of the Meridian, have then Midnight.

P R O B. VII.

A Place, and the Hour at that Place being given; to find what Hour it then is at any other given Place.

Bring the first Place to the graduated Side of the Brazen Meridian, and set the Hour Index to
the

the given Hour; then turn the Globe till the other Place comes to the Meridian, and the Index will point to the Hour required.

P R O B. VIII.

Any Place being given, to move the Globe, so as that Place may be in the Zenith, or that the wooden Horizon shall be an Horizon to the same,

Bring the given Place to the Brazen Meridian; and having found it's Latitude, elevate the Pole, or count from it the same towards the Equator, and fix that Degree to the Notch of the wooden Horizon: The given Place will then be in the Zenith, and the wooden Horizon will be an Horizon to it.

P R O B. IX.

The Latitude of a Place being given, to find the Hour of the Day by the Globe when the Sun shines.

With a Mariners Compass, set the Brazen Meridian due North and South, which is done by causing the North Part of the Meridian to point about 19 Degrees to the East of the *Flower de Luce*; for so much now the Needle varies from pointing truly North and South.

This being done, and Care being taken to have the Globe set on a due Horizontal Plane.

In

In the Summer half Year, or from the 20th of *March* to the 23d of *September*, elevate the Pole to the Latitude.

But in the Winter half Year, or from the 23d of *September* to the 20th Day of *March*, depress the same Pole as much below the opposite Part of the Horizon; and then the Shadow of the Axis of the Globe on the Hour Circle, will shew the Hour of the Day.

P R O B. X.

The Month and Day being given, to find the Sun's Place on the Ecliptic,

Upon the wooden Horizon find the Month and Day, in the *Julian* or *Gregorian* Kalender, as Occasion requires; opposite to which in the inward Circle you have the Sign and Degree of the Sun's Place. Then find that Sign and Degree on the Ecliptic; and a Mark of Chalk being there made, or a very small Bit of Paper being wet and stuck thereon, will shew the Place of the Sun for the given Time.

P R O B. XI.

To find how one Place beareth from another.

By Prob 8. Move the Globe so as that one Place may be in the Zenith: Screw the Quadrant of Altitude on the Meridian over that Place, and flaying the Globe, move the said Quadrant till
it's

it's graduated Edge be brought to pass over the other Place, then that Point of the Compass on the wooden Horizon which is opposite to that Edge, will be the Point that the second Place beareth from the first.

P R O B. XII.

The Day of the Month in any Place whose Latitude is less than $66\frac{1}{2}$ Degrees, being given, to find the Time of the Sun's rising and setting, and the Length of the Day and Night.

Elevate the Globe to the given Latitude; and having found the Sun's Place in the Ecliptic for the given Day, bring it to the Meridian, and set the Hour Index to the upper 12. Then bring the Sun's Place to the East Side of the Horizon, and the Hour Index will point to the Time the Sun rises; and if it be brought to the West Side of the Horizon, the Index will point to the Time of setting.

The Sun's setting being doubled, will give the Length of the Day; and the Sun's rising being doubled, will give the Length of the Night.

Hence it is easy to find the Length of the longest and shortest Day in any Place, whose Latitude is less than $66\frac{1}{2}$ Degrees. For if in the first Case a Mark for the Sun be put on ☉ *Cancer*, and in the second on ♑ *Capricornus*; since in these Places the Sun is, on the longest and shortest Days: The rising and setting of the Sun, may be easily had as
above

above, as well as the Length of the Day and Night.

P R O B. XIII.

The Day and Hour at any Place being given to find where the Sun is vertical, or in the Zenith at that Hour.

Bring the Sun's Place to the Meridian, over which, mark the Degree with Chalk. Then bring the given Place to the Meridian, and set the Index to the given Hour, and turn the Globe till the Index points to 12 at Noon: The Place which is then under the chalked Mark, will be that to which the Sun will be then in the Zenith.

P R O B. XIV.

A Place being given in the Torrid Zone, to find those two Days of the Year, in which the Sun shall be vertical to the same, at 12 at Noon.

Bring the given Place to the Meridian, and with Chalk mark the Degree of Latitude that is above it. Move the Globe till two Points in different Parts of the Ecliptic pass directly under the Mark; and having noted these Points, and found the Sign and Degree of each; then upon the wooden Horizon, find the Days of the Month, which are opposite to each Sign and Degree respectively; and those will be the Days required.

P R O B.

P R O B. XV.

The Day and Hour being given to find all those Places of the Earth, where the Sun is rising, setting, or culminating; and also where it is Day-light, Twilight, or Dark-night.

By Prob. XIII. Find the Place where the Sun is vertical at the given Hour; elevate the Globe to the Latitude of that Place, and bring it to the Meridian. Then all Places that are in the West Semicircle of the Horizon, have the Sun *rising*; those in the East Semicircle have it *setting*; those under the Meridian, above the Horizon, have it *culminating*; and all Places above the Horizon have the Sun so many Degrees above the Horizon as the Places themselves are. Those Places that are below the Horizon, but within 18 Degrees of it, have *Twilight*; and those lower than 18 Degrees have *Dark-Night*.

P R O B. XVI.

A Place, Day and Hour being given, to find the Sun's Height at that Hour

Elevate the Globe to the Latitude of the Place, screw the Quadrant to said Latitude on the Meridian, bring the Sun's Place on the Ecliptic to the Meridian, and set the Index of the Hour-Circle to 12 at Noon; then turn the Globe about untill the Index points to the given Hour, and staying

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it there, bring the Edge of the Quadrant to the Sun, and it will point out it's Height which was required.

P R O B. XVII.

A Place, Day of the Month, and Sun's Height being given, to find the Hour of the Day.

Elevate the Globe, screw the Quadrant to the Latitude, bring the Sun's Place to the Meridian, and set the Hour Index to 12 at Noon; then move the Globe and Quadrant together, so that the Sun's Place on the Ecliptic may correspond with the given Height on the Quadrant; the Hour then pointed to by the Index, will be that required.

P R O B. XVIII.

To find the Time when the Sun begins to appear above the Horizon, and when it begins to disappear, and also the Length of the longest Day or Night, in any Place within the Polar Circles, or whose Latitude is more than $66\frac{1}{2}$ Degrees.

Subtract the Latitude of the given Place from 90, and with a Chalk mark upon the Meridian the remaining Degrees both above and below the Equator: Then move the Globe till two Points of the Ecliptic come directly under the upper Chalk Mark, and having noted these Points, and found the Sign and Degree of each in the Order of the Signs, find the Days of the Month corresponding

ponding with those Places of the Sun upon the wooden Horizon; the first of these will be the Day the Sun begins to appear above the Horizon, and the other the Day it begins to disappear, and consequently the Length of their longest Day will be the Time intercepted between the first and the last of these Days.

The Length of the longest Night is every where equal to the Length of the longest Day, and the Beginning and End of the longest Night may be found in the same Manner that the Beginning and End of the Day was by using the lower Chalk Mark instead of the upper.

P R O B. XIX.

A Place, and the Day of the Month being given, to find the Beginning, End, and Duration of Twilight, and of dark Night.

Elevate the Globe to the given Latitude, and screw the Quadrant of Altitude to that Latitude on the Meridian, bring the Sun's Place to the Meridian, and set the Index of the Hour Circle to 12 at Noon; then bring the Point which is opposite to the Sun's Place to cut 18 Degrees of the Quadrant on the Western and Eastern Sides of the Meridian, and the Index will shew when the Twilight begins or ends:

The Time of the Beginning of Twilight being taken from the Time of the Sun's rising, leaves the Duration of Twilight, and the Time when

Twilight begins being doubled, gives the Length of dark Night.

P R O B. XX.

The Distance between two Places lying under the same Meridian being given, as also their respective bearing from a third Place, to find thereby that Place with it's due Distance from the other two.

Mark the Latitudes of the given Places on the Meridian with Chalk, and keeping them under the said Marks, elevate the Globe to the Latitude of the upper Mark, and fixing the Quadrant of Altitude on said Mark, move it to that Point of the Compass, upon which the third Place bears from it, and make a small Track with Chalk upon the Globe by the Edge of the Quadrant. Then elevate the Globe to the Latitude of the lower Mark, and screw the Quadrant of Altitude to that Latitude, and turn the said Quadrant to that Point of the Compass upon which the third Place bears from it, and observe where the Quadrants Edge intersects the Tract of Chalk, and that will be the third Place required.

Concerning the

Celestial GLOBE.

THE Celestial Globe is supposed to comprehend the Terrestrial one in it's Center. If we imagine the Surface of the Celestial Globe were made of Glafs, and that the Stars were drawn upon it, then a Spectator from the Terrestrial Globe would see the Stars form in a Concave Surface, just as that in the Heavens. The Circles and Points which are peculiar to the Celestial Globe are these.

1. The *Zodiac* is a Hoop or Belt round the Heavens of about 16 Degrees broad, through the Middle of which the Ecliptic or the Sun's annual Path passes.

The *Signs of the Zodiac* are the fixed Stars, which are contained in this Belt, and which for Distinction sake are thrown into 12 Constellations or Asterisms, and are called *Aries*, *Taurus*, &c.

2. The Meridians which pass through *Aries* and *Libra*, and through *Cancer* and *Capricorn*, form two great Circles called *Colures*; the first of which is called the *Equinoctial Colure*, and the other the *Solstitial Colure*.

3 The Points *Aries* and *Libra* are called the *Equinoctial Points*, because when the Sun is in either of them, the Day and Night is every where equal.

4. The

4. The Points *Cancer* and *Capricorn* are called the *Solstitial Points*, because when the Sun is in either of them, he seems to stand still for several Days. When he is in the Solstitial Point *Cancer* he then makes the longest Day, and when in the other, the shortest, to all the Inhabitants of the Northern Hemisphere.

5. That Point in the Heavens which is just over our Head is called the *Zenith*, and the Point opposite to it is called the *Nadir*, and these are the Poles of the Horizon.

Imaginary Circles passing through the *Zenith*, and *Nadir*, and cutting the Horizon at right Angles, are called *Vertical* or *Azimuth Circles*. And the *Azimuth* of the Sun, or a Star is an Arch of the Horizon intercepted between the Meridian, or South Point of the Heavens, and an Azimuth Circle passing through either: Sometimes the Azimuth is reckoned from any other of the Cardinal Points.

When the Azimuth is counted from the East or West to the Sun or a Star at the Time of its rising or setting, it is then called it's *Amplitude*.

6. The *Meridian Altitude* of the Sun, is it's Height above the Horizon at Noon, and when he arrives to that Height, he is said to *Culminate*.

Almicantars, or *Parallels of Altitude*, are imaginary Circles drawn parallel to the Horizon, through every Degree of the vertical Circles.

7. The Poles of the Ecliptic are two Points of the Solstitial Colure, which are $23\frac{1}{2}$ Degrees from the Poles of the World.

8. Great Circles passing through the Poles of the Ecliptic and cutting it at right Angles, are called Circles of Longitude; and if we imagine other Circles to be drawn parallel to the Ecliptic through every Degree of the Circles of Longitude, these will be *Parallels of Latitude* on the Celestial Globe; for Longitude and Latitude on the Celestial Globe, bear just the same Relation to the Ecliptic, as they do on the Terrestrial Globe to the Equator. Thus, as the Longitude of Places on the Earth, is measured from the first Meridian upon the Equator; so the Longitude of the Heavenly Bodies is measured upon the Ecliptic from the first Circle of Longitude, which passes through Aries. And as Latitude on the Earth is counted from the Equator upon the Meridian, so the Latitude of the Heavenly Bodies is measured by Degrees upon a Circle of Longitude counting either North or South from the Ecliptic.

9. The Distance of any Heavenly Body from the Equinoctial measured upon the Meridian, is called it's Declination; therefore all *Parallels of Declination* on the Celestial Globe are the very same as *Parallels of Latitude* on the Terrestrial. What is called Longitude on the Terrestrial Globe, is called *Right Ascension* on the Celestial. viz. The Sun or a Star's Distance from the first Meridian, or that passing through Aries counted upon the Equinoctial.

Oblique Ascension and *Descension* is the Distance of that Point of the Equinoctial from the first of Aries, which in an oblique Sphere rises or sets at the same Time that the Sun or Star rises or sets.

Ascensional

Ascensional Difference is the Difference between right and oblique Ascension; and this turned into Time, by allowing fifteen Degrees for every Hour will shew how much the Heavenly Body rises before or after six o'Clock.

The visible Hemisphere of Stars, is continually changing in a right or oblique Sphere, by Reason of the Suns apparent Motion round the Ecliptic in a Year.

When the Sun gets so near a Star as to hide it in his Beams, it is said to set *Heliacally*, and when after it's Conjunction with the Sun, it becomes again visible, it is said to rise *Heliacally*.

A Star that rises or sets when the Sun rises or sets, is said to rise or set *Cosmically*.

A Star that rises or sets in the Evening when the Sun sets, is said to rise or set *Akronically*.

Of the Divisions of the Heavens, and the Constellations.

Astronomers have divided the Stars into six Classes or Magnitudes, and the Stars of each Magnitude are distinguished by different Marks on the Celestial Globe.

They have also distinguished the Stars into several *Constellations* or *Asterisms*, to which they have given Names; Some have the Names of Men, and others the Names of Beasts, Birds, and several other Things. The Images of those Animals and other Things, from whence the Names of the Constellations are taken, are drawn upon the Celestial

restrial Globe over the several Parcels of Stars which are called by those respective Names.

The Constellations are divided into *Northern* and *Southern*, besides the twelve Signs of the *Zodiac* which lie in the Middle between them.

The Antients formed the Northern Regions into twenty one Constellations viz. *Ursa Minor* or the little Bear; *Ursa Major*, the great Bear; *Draco*, the Dragon; *Cepheus*; *Cassiopeia*; *Andromeda*; *Triangulum*, the Triangle; *Perseus*, with *Medusa's* Head; *Auriga*; *Bootes*; *Corona Septentrionalis*, the Northern Crown; *Hercules*; *Lyra*, the Harp; *Cygnus*, the Swan; *Pegasus* the flying Horse; *Equiculus* the little Horse's Head; *Delphinus* the Dolphin; *Sagitta*, the Arrow; *Aquila*, the Eagle or Vultur; *Serpens*, the Serpent; and *Serpentarius*, the Man who holds it.

To these the Moderns have added *Antoni* near the Eagle; *Coma Berenices*, or Berenice's Hair, near the Lion's Tail; *Leo Minor*, the little Lion, between the great Bear and the Lion, &c.

The Antients formed the Southern Regions into 15 Constellations, viz. *Cetus*, the Whale; the River *Eridanus*; *Lepus*, the Hare; *Orion*, the most glorious Constellation of all; *Canis major*, the great Dog; *Canicula*, the little Dog; *Argo Navis*, the Ship Argo; *Hydra*, the Water Serpent; *Crater*, the Cup; *Corvus* the Crow; *Centaurus*, the Centaur; *Lupus*, the Wolf; *Corona Australis*, the Southern Crown; *Ara*, the Altar; and *Piscis Australis*, the Southern Fish.

To these the Moderns have added twelve Constellations more, which lie so near the South Pole that they cannot be seen by us.

The odd Stars, which are scattered here and there between the Constellations, are called *unformed Stars*.

Some remarkable Parcels of Stars have obtained Names besides those given to the Constellations which contain them, as the *Pleiades* or seven Stars in the Constellation *Taurus*; *Charles's Wain* or *Wagon* consists of seven large bright Stars in the hinder part of the *great Bear*: The three in the Tail are supposed to represent the Horses and the other four the Wain. The two hindermost Stars in the Wain are called the *Pointers*, because they point to the North Star, which is in the Tip of the Tail of the little Bear, that is, a Line drawn through the *Pointers* if continued, will nearly touch the Pole Star. Several single Stars of the first or second Magnitude have Names given them; as *Sirius*, in the great Dog; *Aldebaran*, or the Bull's Eye; *Procyon*, in the little Dog; *Arcturus*, in Bootes; *Regel*, in Orion; *the Lion's Heart*; and *Deneb*, in his Tail; *Spica Virginis*, or the Ear of Corn in the Virgin's Hand; *Castor and Pollux*, in the Constellation *Gemini*; and many others.

The *Galaxy*, *Via Lactea* or milky Way, is a broad irregular whitish Tract in some Places double but for the most Part single, surrounding the whole Heavens. It's bright Appearance is owing to an innumerable Multitude of Stars, which lie quite through it, whose united Rays of Light occasion the shining Whiteness. The modern Astronomers since the Invention of Telescopes, have discovered an innumerable Multitude of Stars, in those Parts which appear only white to the naked
Eye

Eye; and to the same Cause may be ascribed other bright Spots, which lie here and there in the Heavens, as the *Præsepe* or Asses and Manger in the Constellation *Cancer*.

A Connection between the several Parcels of Stars, which form the Constellations, and the Figures after which they are named, can hardly be discovered in the Constellations themselves, except in a very few of them, as *Charles's Wain* may be supposed to resemble a Waggon and three Horses; but a very strong Imagination would find it difficult to discover any such natural Resemblance between the Bulk of the Constellations, and the Figures they are named by.

The Author of *Speſtacle de la Nature* Vol. I. conceives it probable that the Constellations in the Zodiac, were formed and named by the *Egyptians*, who dealt in Hieroglyphics or mystic Figures by which they expressed the Doctrines and Secrets of their Religion, Philosophy and Politics. Thus, a *Lion* was the Hieroglyphic of Strength and Fortitude; a *Horse* of Liberty, a *Circle* of Eternity, &c. now this Author imagines that the 12 Signs of the Zodiac were such Egyptian Hieroglyphics, by which they designed to express or represent some remarkable natural Occurrence in each Month of the Year, as the Sun was passing through the respective Constellations.

The first three Months, beginning from the vernal Equinox were remarkable for the Production of those Animals, which they most used and valued, viz. *Sheep*, *Kine* and *Goats*. The *Lambs* which come first are represented by their Parent the *Ram*;

the *Calves* which come next are represented by the *Bull*; and then the *Kids*, which commonly come in Pairs, therefore gave a Name to the third Constellation. But instead of the *twin Kids*, the *Greeks* have substituted the *twin Brothers Castor and Pollux*.

In the fourth Month, the Sun having arrived at the Summer Solstice, discontinues his Progress towards the North, begins now to go back again to the South, this retrograde Motion the *Egyptians* expressed by the *Crab*, which is said to go backward.

The excessive Heat that usually attends the fifth Month is expressed by the *Lion*, an Animal remarkable for his Strength and Fierceness.

The sixth or the Harvest Month is represented by the *Virgin Reaper, or Gleaner* with an Ear of Corn in her Hand.

The seventh Month, their Sun arrives at the autumnal Equinox, when the Days and Nights are every where equal, and is therefore expressed by the *Ballance, or Scales in Equilibrio*.

October is represented by the *Scorpion*, with a Sting in his Tail, because it is often a sickly Season, occasioned by the Surfeits got in the hot Summer Months.

November being the hunting Season, is represented by the *Sagittary or Archer*.

As the *Crab* represents the backward Motion of the Sun after the Summer Solstice, so in *December*, the *Goat* which delights to browse up Hill, represents the Winter Solstice, because after it, the Sun begins then to ascend or to stretch to the Northward.

January

January is represented by *Aquarius* or the *Waterer*, signifying the Rains and Snows of the Winter Seasons; and *February* is represented by the *two Fishes in a Band*, because this is the prime fishing Season in the Year.

As for the rest of the Constellations which are out of the Zodiac, the Bulk of them were formed by the *Grecians*, who imitated the *Egyptians* in giving the Names of Men, Animals and other Things, to Parcels of Stars; but without any such particular Reasons as the *Egyptians* had, for naming the 12 Signs of the Zodiac.



The Use of the

Celestial G L O B E.

PROBLEM I.

To find the right Ascension and Declination of any Star.

BRING the Star to the graduated Edge of the Brazen Meridian, and the Degree over it will be it's Declination; then observe the Degree of the Equinoctial that is at the same Time under the graduated Edge of the Meridian, and that will be its right Ascension.

P R O B. II.

To find the Latitude and Longitude of any Star.

Bring the Pole of the Ecliptic to the graduated Edge of the Meridian, over which screw the Quadrant of Altitude and elevate the Globe to $66\frac{1}{2}$ Degrees or to the Distance of the Polar Circles from the Equator, and then the Ecliptic will coincide with the Horizon: Stay the Globe in this Position and turn the Edge of the Quadrant of Altitude to the Star; then the Degree on the Quadrant which meets the Star, will be it's Latitude, and
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the Degree on the Ecliptic which is cut by the Edge of the Quadrant is the Degree of it's Longitude.

P R O B. III.

To find the rising and setting of any Star for any given Time and Place.

Elevate the Globe to the Latitude of the Place, find the Sun's Place for the given Day on the Ecliptic, and bring it to the graduated Edge of the Brazen Meridian, and put the Index of the Hour Circle to 12 at Noon: Then bring the Star to the East Part of the Horizon and the Index will shew the Time of it's Rising and it will tell the Setting, if the Star be brought to the West Part of the Horizon.

N. B. In like Manner the Rising and Setting of any Planet may be found, by putting a small Bit of Paper to represent it's Place in the Ecliptic, which may be known at any Time by an *Ephemeris*.

P R O B. IV.

How to distinguish one Star from another, and to know the Situation of the Heavens for any given Time.

Elevate the Globe to the Latitude of the Place you are in, and having marked the Sun, Moon, and Planets on small Bits of Paper, stick them in their respective Places on the Ecliptic; bring the
Sun

Sun to the Meridian and set the Index of the Hour Circle to 12 at Noon, and set the Meridian of the Globe due North and South by the Compass.

Then turn the Globe till the Index Points to the Hour of the Night, at which you make your Observation, and every Star and Planet, which is then above the Horizon, will coincide with it's Original in the Heavens: For if Lines drawn from the Center of the Globe to every Star on it's Surface, were continued to the Heavens, each would pass through it's Original; or if the Globe were transparent, and the Observer's Eye in it's Center, every Star on the Globe would cover it's real Star in the Heavens. So that by learning the Names given them on the Globe, you may by Degrees become so well acquainted with the Heavens, as to be able to tell at any Time, what Stars they are that lie here or there.

P R O B. V.

The Place and Day being given, to find the Sun or Stars Eastern or Western Amplitude, oblique Ascension and Descension, ascensional Difference, and Semi-diurnal Arch.

Elevate for the Latitude, and bring the Sun's Place or the Star to the East or West Part of the Horizon; then the Arch between it, and the East or West Point of the Horizon shews it's Eastern and Western *Amplitude*. The Degree of the Equinoctial, where it cuts the Horizon shews the *oblique Ascension* or *Descension*; and the Difference between
the

the right and oblique Ascension (or if it be of the Sun, the Difference between the Hour which the Index points to, and Six) is the ascensional Difference, which being converted into Time, and added to Six, when the Sun or Star declines towards the elevated Pole, *i. e.* in Northern Latitude, when it is North Declination, or subtracted from Six when it declines towards the depressed Pole, gives half the Time of its Stay above the Horizon; which when we speak of the Sun, is called the *semidiurnal Arch*. The Compliment of the semidiurnal Arch to 12, gives the *seminocturnal Arch* or half the Time of it's Stay below the Horizon. The Sun's semidiurnal Arch computed from Noon, gives the Time of it's setting, and his seminocturnal Arch computed from Midnight, gives the Time of his rising.

P R O B. VI.

The Latitude and Sun's Place being known, and if either the Hour of the Day, or the Altitude, or Azimuth of the Sun or Star be given, to find the other two.

Elevate for the Latitude, bring the Sun's Place to the Meridian, fix the Index of the Hour Circle to 12 at Noon, and screw the Quadrant of Altitude to the Latitude; then,

1st. If the *Hour* be given, turn the Globe till the Index points to it, and bring the Quadrant of Altitude to the Place of the Sun or Star; then will its graduated Edge shew the Degree of Altitude

tude, and the Degree of the Horizon where the Quadrant cuts it, shews the Sun's Azimuth or Bearing.

2d. If the *Altitude* be given, bring the Sun or Stars Place to meet with the Quadrant at the given Altitude, then the Index will Point to the Hour, and the Intersection of the Quadrant and Horizon will shew the Azimuth.

3. If the *Azimuth* be given, bring the Quadrant to intersect the Horizon at the given Azimuth; then by turning the Globe, bring the Sun's Place or Star to the graduated Edge of the Quadrant, and the Degree of the Quadrant where they meet shews the Altitude, and the Index points to the Hour.

Hence if the Altitude and Azimuth of any Star be found by Observation, it will be easy to find that Star on the Globe; and by taking the Altitude and Azimuth of any Star on the Globe at a given Hour, the Star may be found in the Heavens.

P R O B. VII.

The Latitude of a Place being given, to find the Cosmical rising and setting of any given Star.

For the Rising.

Elevate for the Latitude, and bring the Star to the Eastern Part of the Horizon: See what Degree of the Ecliptic is then rising, and answering to that Degree in the Kalendar on the Horizon, you will find the Day required.

For

For the Setting.

Elevate as before, bring the given Star to the Western Part of the Horizon, then observe what Degree of the Ecliptic is rising to the East, and over against it as before, the Day may be found. Thus, Latitude $53\frac{1}{2}$ N *Sirius* rises Cosmically; the 13th of *August*, and sets Cosmically the 12th of *November*.

P R O B. VIII.

The Latitude of a Place being given to find the Archronical Rising or Setting of any Star.

For the Rising

Elevate for the Latitude, bring the given Star to the Eastern Part of the Horizon; then see what Degree of the Ecliptic is cut by the Western Part of the Horizon, the Day answering to that Degree will be the Day required.

For the Setting.

Elevate as before, bring the Star to the Western Part of the Horizon, and see what Degree of the Ecliptic is then setting, and opposite to it in the Kalendar, you will have the Day required. Thus, *Sirius* rises Achronically the 9th of *February*, and sets the 11th of *May*.

P R O B. IX.

The Day of the Month being given, to find when any Star will come to the Meridian.

Elevate for the Latitude, bring the Sun's Place to the Meridian, and put the Hour Index to 12 at Noon, then turn the Globe till the given Star come to the Meridian, and the Index will point to the Time required.

P R O B. X.

To find when a given Star will come to the Meridian at any given Hour of the Night.

Bring the given Star to the Meridian, set the Index at 12 at Noon, then turn the Globe Eastward till the Index points to an Hour, that is far before 12 in the Forenoon, as the given Hour is after 12 in the Afternoon; observe the Degree of the Ecliptic then at the Meridian, over against which in the Kalendar is the Day of the Month when the given Star will be upon the Meridian at the given Hour.

Many more Problems might be inserted upon this Head, but these will be found to be so far sufficient, that if a Person is Master of them, he will readily be able to work any he may meet with in other Authors.

Agnes Kinnear
Miss Johnstone
Mary Smith
Thurston
Wm. Smith
John Smith

and have been Chap
as an officer in the

The above
Thos. J. M.

[illegible]

Catherine Bush

Chas. B.

Chas.

